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Environmental Protection Agency

40 CFR Parts 69, 80, 89, et al.

Control of Emissions of Air Pollution From Nonroad Diesel Engines and Fuel; Proposed Rule

ENVIRONMENTAL PROTECTION AGENCY

40 CFR Parts 69, 80, 89, 1039, 1065, and 1068

[AMS–FRL–7485–8]

RIN 2060–AK27

Control of Emissions of Air Pollution From Nonroad Diesel Engines and Fuel

AGENCY: Environmental Protection Agency (EPA).

ACTION: Notice of proposed rulemaking.

SUMMARY: Nonroad diesel engines contribute considerably to our nation's air pollution. These engines, used primarily in construction, agricultural, and industrial applications, are projected to continue to contribute large amounts of particulate matter (PM), nitrogen oxides (NO_X), and sulfur oxides (SO_X), all of which contribute to serious public health problems in the United States. These problems include premature mortality, aggravation of respiratory and cardiovascular disease, aggravation of existing asthma, acute respiratory symptoms, chronic bronchitis, and decreased lung function. We believe that diesel exhaust is likely to be carcinogenic to humans by inhalation.

Today EPA is proposing new emission standards for nonroad diesel engines and sulfur reductions in nonroad diesel fuel that will dramatically reduce emissions attributed to nonroad diesel engines. This comprehensive national program will regulate nonroad diesel engines and diesel fuel as a system. New engine standards will begin to take effect in the 2008 model year. These standards are based on the use of advanced exhaust emission control devices. We estimate PM reductions of 95%, NO_X reductions of 90%, and the virtual elimination of sulfur oxides (SO_X) from nonroad engines meeting the new standards. Nonroad diesel fuel sulfur reductions of up to 99% from existing levels will provide significant health benefits as well as facilitate the introduction of high-efficiency catalytic exhaust emission control devices as these devices are damaged by sulfur. These fuel controls would begin in mid-2007. Today's nonroad proposal is largely based on EPA's 2007 highway diesel program.

To better ensure the benefits of the standards are realized in-use and throughout the useful life of these engines, we are also proposing new test procedures, including not-to-exceed requirements, and related certification requirements. The proposal also includes provisions to facilitate the transition to the new engine and fuel standards and to encourage the early introduction of clean technologies and clean nonroad diesel fuel. We have also developed provisions for both the proposed engine and fuel programs designed to address small business considerations.

The requirements in this proposal would result in substantial benefits to public health and welfare and the environment through significant reductions in emissions of NO_X and PM, as well as nonmethane hydrocarbons (NMHC), carbon monoxide (CO), sulfur oxides (SO_X) and air toxics. We project that by 2030, this program would reduce annual emissions of NO_X, and PM by 827,000 and 127,000 tons, respectively. These emission reductions would prevent 9,600 premature deaths, over 8,300 hospitalizations, and almost a million work days lost, and other quantifiable benefits every year. All told the benefits of this rule would be approximately $81 billion annually by 2030. Costs for both the engine and fuel requirements would be many times less, at approximately $1.5 billion annually.

DATES: Comments: Send written comments on this proposal by August 20, 2003. *See* section IX for more information about written comments.

Hearings: We will hold public hearings on the following dates: June 10, 2003; June 12, 2003; and June 17, 2003. Each hearing will start at 9 a.m. local time. If you want to testify at a hearing, notify the contact person listed below at least 10 days before the hearing. *See* section IX for more information about public hearings.

ADDRESSES: Comments: Comments may be submitted by mail to: Air Docket, Environmental Protection Agency, Mailcode: 6102T, 1200 Pennsylvania Ave., NW., Washington, DC 20460, Attention Docket ID No. A–2001–28.

Comments may also be submitted electronically, by facsimile, or through hand delivery/courier. Follow the detailed instructions as provided in section IX of the **SUPPLEMENTARY INFORMATION** section.

Hearings: We will hold public hearings at the following three locations:

New York, New York, Park Central New York, 870 Seventh Avenue at 56th Street, New York, NY 10019, Telephone: (212) 247–8000, Fax: (212) 541–8506.	June 10, 2003
Chicago, Illinois, Hyatt Regency O'Hare, 9300 W. Bryn Mawr Avenue, Rosemont, IL 60018, Telephone: (847) 696–1234, Fax: (847) 698–0139.	June 12, 2003.
Los Angeles. California, Hyatt Regency Los Angeles, 711 South Hope Street, Los Angeles, California, USA. 90017, Telephone: (213) 683–1234, Fax: (213) 629–3230.	June 17, 2003.

See section IX, "Public Participation" below for more information on the comment procedure and public hearings.

FOR FURTHER INFORMATION CONTACT: U.S. EPA, Office of Transportation and Air Quality, Assessment and Standards Division hotline, (734) 214–4636, *asdinfo@epa.gov.* Carol Connell, (734) 214–4349; *connell.carol@epa.gov.*

SUPPLEMENTARY INFORMATION:

Regulated Entities

This action would affect you if you produce or import new heavy-duty diesel engines which are intended for use in nonroad vehicles such as agricultural and construction equipment, or produce or import such nonroad vehicles, or convert heavy-duty vehicles or heavy-duty engines used in nonroad vehicles to use alternative fuels. It would also affect you if you produce, import, distribute, or sell nonroad diesel fuel, or sell nonroad diesel fuel.

The following table gives some examples of entities that may have to follow the regulations. But because these are only examples, you should carefully examine the regulations in 40 CFR parts 80, 89, 1039, 1065, and 1068. If you have questions, call the person listed in the **FOR FURTHER INFORMATION CONTACT** section of this preamble:

Category	NAICS codes [a]	SIC codes [b]	Examples of potentially regulated entities
Industry	333618	3519	Manufacturers of new nonroad diesel engines.

Category	NAICS codes[a]	SIC codes[b]	Examples of potentially regulated entities
Industry	333111	3523	Manufacturers of farm machinery and equipment.
Industry	333112	3524	Manufacturers of lawn and garden tractors (home).
Industry	333924	3537	Manufacturers of industrial trucks.
Industry	333120	3531	Manufacturers of construction machinery.
Industry	333131	3532	Manufacturers of mining machinery and equipment.
Industry	333132	3533	Manufacturers of oil and gas field machinery and equipment.
Industry	811112 811198	7533 7549	Commercial importers of vehicles and vehicle components.
Industry	324110	2911	Petroleum refiners.
Industry	422710 422720	5171 5172	Diesel fuel marketers and distributors.
Industry	484220 484230	4212 4213	Diesel fuel carriers.

[a] North American Industry Classification System (NAICS).
[b] Standard Industrial Classification (SIC) system code.

How Can I Get Copies of This Document and Other Related Information?

Docket. EPA has established an official public docket for this action under Docket ID No. A–2001–28. The official public docket consists of the documents specifically referenced in this action, any public comments received, and other information related to this action. Although a part of the official docket, the public docket does not include Confidential Business Information (CBI) or other information whose disclosure is restricted by statute. The official public docket is the collection of materials that is available for public viewing at the Air Docket in the EPA Docket Center, (EPA/DC) EPA West, Room B102, 1301 Constitution Ave., NW., Washington, DC. The EPA Docket Center Public Reading Room is open from 8:30 a.m. to 4:30 p.m., Monday through Friday, excluding legal holidays. The telephone number for the Reading Room is (202) 566–1742, and the telephone number for the Air Docket is (202) 566–1742.

Electronic Access. You may access this **Federal Register** document electronically through the EPA Internet under the ''**Federal Register**'' listings at *http://www.epa.gov/fedrgstr/.*

An electronic version of the public docket is available through EPA's electronic public docket and comment system, EPA Dockets. You may use EPA Dockets at *http://www.epa.gov/edocket/* to submit or view public comments, access the index listing of the contents of the official public docket, and to access those documents in the public docket that are available electronically. Once in the system, select ''search,'' then key in the appropriate docket identification number.

Certain types of information will not be placed in the EPA Dockets. Information claimed as CBI and other information whose disclosure is restricted by statute, which is not included in the official public docket, will not be available for public viewing in EPA's electronic public docket. EPA's policy is that copyrighted material will not be placed in EPA's electronic public docket but will be available only in printed, paper form in the official public docket. To the extent feasible, publicly available docket materials will be made available in EPA's electronic public docket. When a document is selected from the index list in EPA Dockets, the system will identify whether the document is available for viewing in EPA's electronic public docket. Although not all docket materials may be available electronically, you may still access any of the publicly available docket materials through the docket facility identified in section IX.

For public commenters, it is important to note that EPA's policy is that public comments, whether submitted electronically or in paper, will be made available for public viewing in EPA's electronic public docket as EPA receives them and without change, unless the comment contains copyrighted material, CBI, or other information whose disclosure is restricted by statute. When EPA identifies a comment containing copyrighted material, EPA will provide a reference to that material in the version of the comment that is placed in EPA's electronic public docket. The entire printed comment, including the copyrighted material, will be available in the public docket.

Public comments submitted on computer disks that are mailed or delivered to the docket will be transferred to EPA's electronic public docket. Public comments that are mailed or delivered to the Docket will be scanned and placed in EPA's electronic public docket. Where practical, physical objects will be photographed, and the photograph will be placed in EPA's electronic public docket along with a brief description written by the docket staff.

For additional information about EPA's electronic public docket visit EPA Dockets online or *see* 67 FR 38102, May 31, 2002.

Outline of This Preamble

I. Overview

Nonroad diesel engines are the largest remaining contributor to the overall mobile source emissions inventory. We have already taken steps to dramatically reduce emissions from light-duty vehicles and heavy-duty vehicles and engines through the Tier 2 and 2007 highway diesel programs.[1] With expected growth in the nonroad sector, the relative emissions contribution from nonroad diesel engines is projected to be even larger in future years. This proposed rule sets out emissions standards for nonroad diesel engines used mainly in construction, agricultural, industrial, and mining operations that will achieve reductions in PM and NO_X emissions levels from today's engines in excess of 95% and 90%, respectively. Nonroad diesel fuel is currently unregulated. This proposal represents the first time nonroad diesel fuel will be regulated. We are proposing to reduce sulfur levels in nonroad diesel fuel by more than 99 percent to 15 parts per million (ppm). Taken together, controls included in this proposal would result in large public health and welfare benefits.

The proposed standards for nonroad diesel engines and sulfur reductions for nonroad diesel fuel represent a dramatic step in emissions control, based on the use of advanced emissions control technology. Until the mid-90's, these engines had no emissions requirements. As a comparison, cars and trucks have been subject to a series of increasingly stringent emissions control programs since the 1970s. In terms of fuel quality requirements, nonroad diesel fuel is currently uncontrolled at the Federal level. EPA has already issued rules ending these disparities for diesel engines used in highway applications. Starting in 2007, these engines will meet standards of the same level of stringency as comparable gasoline vehicles, based on the use of advanced aftertreatment technologies and ultra low sulfur diesel fuel (containing no more than 15 ppm sulfur). This proposal is largely based on the performance of the same advanced aftertreatment technologies, and would bring nonroad diesel fuel to the same 15 ppm cap for sulfur that will be required for highway diesel fuel starting in 2006. We believe it is highly appropriate to propose dramatic steps forward in emissions standards and reductions in sulfur levels in nonroad diesel fuel. As discussed throughout this proposal, such steps represent a feasible progression in the application of advanced emissions control technologies, would achieve needed production of low sulfur diesel fuel to enable the advanced emission control technologies, the standards are cost-effective, and provide very large public health and welfare benefits.

We followed certain principles when developing the elements of this proposal. First, the program must achieve reductions in NO_X, SOx, and PM emissions as early as possible. This includes reductions from the in-use fleet of nonroad diesel engines. Second, as we did in the 2007 highway diesel program, we are treating vehicles and fuels as a system since we believe this is the best way to achieve the greatest emissions reductions. Third, the implementation of low sulfur requirements for nonroad diesel fuel must in no way interfere with the implementation and expected benefits of introducing ultra low sulfur fuel in the highway market, as required by the 2007 highway diesel program. Lastly, the program must provide sufficient lead time to allow the integration of advanced emissions control technologies from the highway sector onto nonroad diesel engines as well as the expansion of ultra low sulfur fuel production to the nonroad market.

This proposal sets out new engine exhaust emissions standards, emissions test procedures, including not-to-exceed requirements, for nonroad engines, and sulfur control requirements for nonroad, locomotive, and marine diesel fuel. The proposed exhaust standards would

[1] *See* 65 FR 6698 (February 10, 2000) and 66 FR 5001 (January 18, 2001) for the final rules regarding the Tier 2 and 2007 highway diesel programs, respectively.

result in particulate matter (PM) and nitrogen oxide (NO_X) emissions levels that are in excess of 95 percent and 90 percent, respectively, below comparable levels in effect today. They will begin to take effect in the 2008 model year, with a phase-in of standards across five different engine power rating groupings. New engine emissions test procedures are proposed to take effect with these new standards to better ensure emissions control over real-world engine operation and to help provide for effective compliance determination. Diesel fuel used in nonroad, locomotive, and marine applications would meet a 500 ppm cap starting in June 2007, a reduction of approximately 90%. There are large benefits to taking this first sulfur reduction action, especially in the reduction of particulate matter from the in-use fleet. In 2010, sulfur levels in nonroad diesel fuel (though not locomotive or marine diesel fuel) would meet a 15 ppm cap, for a total reduction of over 99%. While there are important health and welfare benefits associated with the reduction from 500 ppm to 15 ppm, the main benefit will be to facilitate the introduction of advanced aftertreatment devices on nonroad engines, which would in turn lead to significant benefits. We are also seeking comment on and seriously considering applying the 15 ppm cap to locomotive and marine diesel fuel.

The requirements in this proposal would result in substantial benefits to public health and welfare and the environment through significant reductions in emissions of NO_X and PM, as well as nonmethane hydrocarbons (NMHC), carbon monoxide (CO), sulfur oxides (SO_X) and air toxics. We project that by 2030, this program would reduce annual emissions of NO_X, and PM by 827,000, and 127,000 tons, respectively. These annual emission reductions would prevent 9,600 premature deaths, over 8,300 hospitalizations, and almost a million work days lost, among quantifiable benefits. The overall quantifiable benefits of this rule would be approximately $81 billion annually by 2030. Costs for both the engine and fuel requirements would be significantly less, at approximately $1.5 billion annually.

A. What Is EPA Proposing?

This proposal is a further step in EPA's long-term program to control emissions from nonroad diesel engines. The EPA has taken measures to reduce harmful emissions from nonroad diesel engines in two past regulatory actions. A 1994 final rule, developed under provisions of section 213 of the Clean Air Act, set initial emissions standards for new nonroad diesel engines greater than 50 hp (59 FR 31306, June 17, 1994). These standards gained modest reductions in NO_X emissions and are referred to as EPA's ''Tier 1'' standards for large nonroad engines. A subsequent final rule published in 1998 set more stringent Tier 2 and Tier 3 standards for these engines, as well as Tier 1 and Tier 2 standards for the nonroad diesel engines under 50 hp (63 FR 56968, October 23, 1998). Nonroad diesel fuel quality is not presently regulated by the EPA.

We also expressed our intent in the 1998 final rule to continue evaluating the rapidly changing state of diesel emissions control technology, and to perform a review in the 2001 timeframe of the technological feasibility of the Tier 3 standards, and of the Tier 2 standards for engines rated under 50 hp. This review was completed in 2001 and documented in an EPA staff technical paper that confirmed the feasibility of those standards, finding that the number of potential control options had expanded since the 1998 final rule to include new technologies and more effective application of existing technologies.[2]

There are two basic parts to this proposed program: (1) New exhaust emission standards and test procedures for nonroad diesel engines, and (2) new sulfur limits for nonroad, locomotive, and marine diesel fuel. The systems approach of combining the engine and fuel standards into a single program is critical to the success of our overall efforts to reduce emissions, because the emission standards will not be feasible without the fuel change. This proposal is largely based on the 2007 highway diesel program.

We looked at a number of alternative program options, as discussed in more detail in section VI below and chapter 12 of the draft Regulatory Impact Analysis (RIA). For example, we analyzed a program that would require refiners to produce 15 ppm nonroad diesel fuel starting in 2008, with appropriate engine standards phased-in beginning in 2009. Many of these alternatives provided a very similar level of projected emissions control and health and welfare benefits as our proposed program. However, taking into account the need for appropriate lead time, achieving the greatest possible emissions reductions as early as possible, and the interaction of requirements in this proposal with existing highway diesel engine environmental programs, we believe our proposed program provides the best opportunity for achieving all of our goals, as described above, including timely and significant emissions reductions from nonroad diesel engines and the associated introduction of ultra low sulfur nonroad diesel fuel. We are asking for comments on the alternatives discussed in this proposal.

The elements of the rule are outlined below. Detailed provisions and justifications for our proposed rule are discussed in subsequent sections and the draft RIA.

1. Nonroad Diesel Engine Emission Standards

Today's action proposes standards for nonroad diesel engines ranging from 3 to over 3,000 horsepower. Applicable emissions standards are determined by year for each of five engine power band categories. For engines less than 25 hp, we are proposing new engine standards for PM (0.30 g/bhp-hr) and CO (4.9 g/bhp-hr) to go along with existing NO_X standards beginning in 2008. For engines between 25–75 hp, we are proposing standards reflecting approximately 50% reduction in PM control from today's engines applicable in 2008. Then, starting in 2013, PM standards of 0.02 g/bhp-hr and NO_X standards of 3.5 g/bhp-hr would apply. For engines between 75–175 hp, the proposed standards would be 0.01 g/bhp-hr for PM, 0.30 g/bhp-hr for NO_X, and 0.14 g/bhp-hr for HC beginning in 2012. These same standards would apply for both engines between 175–750 hp and greater than 750 hp starting in 2011. These PM, NO_X, and NMHC standards are similar in stringency to the final standards included in the 2007 highway diesel program and are expected to require the use of high-efficiency aftertreatment systems to ensure compliance. Thus, virtually all nonroad diesel engines after 2013 would likely be using advanced aftertreatment systems. We are phasing in many of these proposed standards over a period of three years in order to address lead time, workload, and feasibility considerations.

We are also proposing to continue the averaging, banking, and trading nonroad emissions credits provisions to demonstrate compliance with the standards. In addition, we are proposing to include turbocharged diesels in the existing prohibition on crankcase emissions, effective in the same year that the proposed Tier 4 standards first apply in each power category. More specific information on the proposed standards can be found in section III below.

[2] ''Nonroad Diesel Emissions Standards Staff Technical Paper'', EPA420–R–01–052, October 2001.

To better ensure the benefits of the standards are realized in-use and throughout the useful life of these engines, we are also proposing new test procedures and related certification requirements. We believe the new supplemental transient test, Constant Speed Variable Load transient duty cycle, cold start transient test, and not-to-exceed test procedures and standards will all help achieve our goal. This is a significant and important aspect of this proposal that would bring greater confidence and certainty to the compliance program.

The proposal also includes provisions to facilitate the transition to the new engine and fuel standards and to encourage the early introduction of clean technologies. We are also including proposed adjustments to various fuel and engine testing and compliance requirements. These provisions are described further in sections III, IV, and VI.

2. Nonroad, Locomotive, and Marine Diesel Fuel Quality Standards

We are proposing that sulfur levels for nonroad diesel fuel be reduced from current uncontrolled levels ultimately to 15 ppm, though we are proposing an interim cap of 500 ppm. Beginning June 1, 2007, refiners would therefore be required to produce nonroad, locomotive, and marine diesel fuel that meets a maximum sulfur level of 500 ppm. This does not include diesel fuel for home heating, industrial boiler, or stationary power uses or diesel fuel used in aircraft. We estimate there are significant health and welfare benefits associated with this proposed reduction, including reductions in sulfate emissions and reduced engine operating expenses. Then, beginning in June 1, 2010, fuel used for nonroad diesel applications (excluding locomotive and marine engines) is proposed to meet a maximum sulfur level of 15 ppm, since all 2011 and later model year nonroad diesel-fueled engines with aftertreatment must be refueled with this new ultra low sulfur diesel fuel. This sulfur standard is based on our assessment of the impact of sulfur on advanced exhaust emission control technologies and a corresponding assessment of the feasibility of ultra low sulfur fuel production and distribution. We are also asking for comment on bringing sulfur levels for locomotive and marine fuel to 15 ppm in 2010 and note that we anticipate beginning the process of developing new engine controls for these two sources in 2004. This proposal includes a combination of provisions available to refiners, especially small refiners, to ensure a smooth transition to ultra low sulfur nonroad diesel fuel.

In addition, this proposal includes unique provisions for implementing the ultra low sulfur diesel fuel program in the State of Alaska. We are also proposing that certain U.S. territories be excluded from both the nonroad engine standards and diesel fuel standards. Similar actions were taken as part of the 2007 highway diesel program.

The compliance provisions for ensuring diesel fuel quality are essentially consistent with those that have been in effect since 1993 for highway diesel fuel, reflecting updated requirements that were included in the 2007 highway diesel program. Additional compliance provisions are proposed for the transition years of the program concerning the interaction of the nonroad, locomotive, and marine sulfur control requirements with existing highway diesel sulfur control provisions. These provisions could also help discourage misfueling of nonroad equipment utilizing high-efficiency aftertreatment devices. The proposed compliance requirements include provisions that would prohibit equipment operators from fueling their machines with higher sulfur fuels after completion of the shift to lower sulfur nonroad diesel fuels, regardless of the age of their equipment.

B. Why Is EPA Making This Proposal?

1. Nonroad, Locomotive, and Marine Diesels Contribute to Serious Air Pollution Problems

As discussed in detail in section II and chapter 2 and 3 of draft RIA, emissions from nonroad, locomotive, and marine diesel engines contribute greatly to a number of serious air pollution problems, and these emissions would have continued to do so into the future absent further controls to reduce them. First, these engines contribute to the health and welfare effects associated with ozone, PM, NO_X, SO_X, and volatile organic compounds (VOCs), including toxic compounds such as formaldehyde. These adverse effects include premature mortality, aggravation of respiratory and cardiovascular disease (as indicated by increased hospital admissions and emergency room visits, school absences, work loss days, and restricted activity days), changes in lung function and increased respiratory symptoms, changes to lung tissues and structures, altered respiratory defense mechanisms, chronic bronchitis, and decreased lung function.[3 4 5] Second and importantly, in addition to its contribution to ambient PM inventories, diesel exhaust is of specific concern because it has been judged to likely pose a lung cancer hazard for humans as well as a hazard from noncancer respiratory effects. The Agency has classified diesel exhaust as likely to be carcinogenic to humans by inhalation at environmental exposures. Third, ozone and PM cause significant public welfare harm. Specifically, ozone causes damage to vegetation which leads to economic crop and forestry losses, as well as harm to national parks, wilderness areas, and other natural systems. PM causes damage to materials and soiling of commonly used building materials and culturally important items such as statues and works of art. Fourth, NO_X, SO_X and direct emissions of PM contribute to substantial visibility impairment in many parts of the U.S. where people live, work, and recreate, including mandatory Federal Class I areas. Finally, NO_X emissions from nonroad diesel engines contribute to the acidification, nitrification and eutrophication of water bodies.

Millions of Americans live in areas with unhealthful air quality that may endanger public health and welfare (*i.e.,* levels not requisite to protect the public health with an adequate margin of safety). Based upon data for 1999–2001, there are 291 counties that are violating the 8-hour ozone NAAQS, totaling 111 million people. In addition, at least 65 million people in 129 counties live in areas where annual design values of ambient $PM_{2.5}$ violate the $PM_{2.5}$ NAAQS. There are an additional 9 million people in 20 counties where levels above the $PM_{2.5}$ NAAQS are being measured, but the data are incomplete. Without emission reductions from the proposed new standards for nonroad engines, there is a significant future risk that 32 counties with 47 million people across the country may violate the 8-hour ozone national ambient air quality standard (NAAQS) in 2030, based on our modeling. Similarly, modeled $PM_{2.5}$ concentrations in 107 counties where 85 million people live are above specified levels in 2030. An additional 64 million people are projected to live in counties

[3] U.S. EPA (1996) Air Quality Criteria for Particulate Matter—Volumes I, II, and III, EPA Office of Research and Development, National Center for Environmental Assessment, July 1996. Report No. EPA/600/P–95/001aF, EPA/600/P–95/001bF, EPA/600/P–95/001cF.

[4] U.S. EPA (2002), Air Quality Criteria for Particulate Matter—Volumes I and II (Third External Review Draft). This material is available electronically at *http://cfpub.epa.gov/ncea/cfm/partmatt.cfm.*

[5] U.S. EPA (1996) Air Quality Criteria for Ozone and Related Photochemical Oxidants. EPA Office of Research and Development, National Center for Environmental Assessment, July 1996. Report No. EPA/600/P–93/004aF. The document is available on the Internet at *http://www.epa.gov/ncea/ozone.htm.*

within 10 percent of the $PM_{2.5}$ standard in 2030, and 44 million people are projected to live in counties within 10 percent of the level of the 8-hour standard in 2030. Thus, our analyses show that these counties face a significant risk of exceeding or failing to maintain the $PM_{2.5}$ and the 8-hour ozone NAAQS without significant additional controls between 2007 and 2030.

Federal, State and local governments are working to bring ozone and particulate levels into compliance with the NAAQS through State Implementation Plan (SIP) attainment and maintenance plans, and to ensure that future air quality reaches and continues to achieve these health- and welfare-based standards. The reductions in this proposed rulemaking will play a critical part in these important efforts to attain and maintain the NAAQS. In addition, reductions from this action will also reduce public health and welfare effects associated with maintenance of the 1-hour ozone and PM_{10} NAAQS.

Emissions from nonroad, locomotive, and marine diesel engines account for substantial portions of the country's ambient PM and NO_X levels. NO_X is a key precursor to ozone and PM formation. We estimate that these engines account for about ten percent of total NO_X emissions and about ten percent of total PM emissions. These proportions are even higher in some urban areas, where these engines contribute up to 19 percent of the total NO_X emissions and up to 18 percent of the total PM emissions inventory. Over time, the relative contribution of these diesel engines to air quality problems will go even higher unless EPA takes action to further reduce pollution levels. For example, EPA has already taken steps to bring emissions levels from light-duty and heavy-duty vehicles and engines to near-zero levels by the end of this decade. The PM and NO_X standards for nonroad, locomotive, and marine diesel engines in this proposal would have a substantial impact on emissions. By 2030, NO_X emissions from these diesel engines under today's standards will be reduced by 827,000 tons, and PM emissions will decline by about 127,000 tons, dramatically reducing this source of NO_X and PM emissions. Urban areas, which include many poorer neighborhoods, can be disproportionately impacted by such diesel emissions, and these neighborhoods will thus receive a relatively larger portion of the benefits expected from proposed emissions controls. Diesel exhaust is of special concern because it is associated with increased risk of lung cancer and respiratory disease. EPA recently issued its Health Assessment Document for Diesel Exhaust.[6] The Agency has classified diesel exhaust as likely to be carcinogenic to humans by inhalation at environmental exposures. State and local governments, in their efforts to protect the health of their citizens and comply with requirements of the Clean Air Act (CAA or "the Act"), have recognized the need to achieve major reductions in diesel PM emissions, and have been seeking Agency action in setting stringent new standards to bring this about.[7]

2. Technology and Fuel Based Solutions

Although the air pollution from nonroad diesel exhaust is challenging, we believe they can be addressed through the application of high-efficiency emissions control technologies. As discussed in much greater detail in section III, the development of diesel emissions control technology has advanced in recent years so that very large emission reductions (in excess of 90 percent) are possible, especially through the use of catalytic emission control devices installed in the nonroad equipment's exhaust system and integrated with the engine controls. These devices are often referred to as "exhaust emission control" or "aftertreatment" devices. Exhaust emission control devices, in the form of the well-known catalytic converter, have been used in gasoline-fueled automobiles for 28 years.

Based on the Clean Air Act requirements in section 213, we are proposing stringent new emission standards that will result in the use of these diesel exhaust emission control devices. We are also proposing changes to nonroad diesel fuel quality standards, under section 211(c) of the Act, in order to enable these high-efficiency technologies.

To meet the proposed new standards, application of high-efficiency exhaust emission controls for both PM and NO_X will be needed for most engines. High-efficiency PM exhaust emission control technology has been available for several years. This technology has continued to improve over the years, especially with respect to durability and robust operation in use. It has also proved extremely effective in reducing exhaust hydrocarbon emissions. Thousands of such systems are now in use, especially in Europe. It is the same technology we expect to be applied to meet the PM standards in the 2007 heavy-duty highway diesel engine rule. However, as discussed in detail in section III, these systems are very sensitive to sulfur in the fuel. For the technology to be viable and capable of meeting the standards, we believe it will require diesel fuel with sulfur content capped at the 15 ppm level.

Similarly, high-efficiency NO_X exhaust emission control technology will be needed if nonroad diesel engines are to attain the proposed standards. This is the same technology that we anticipate will be applied to heavy-duty highway diesel engines to meet the NO_X standards included in the 2007 highway diesel program. This technology, like the PM technology, is dependant on the 15 ppm maximum nonroad diesel fuel levels being proposed in this action in order to be feasible and capable of achieving the standards. Similar high-efficiency NO_X exhaust emission control technology has been quite successful in gasoline direct injection engines that operate with an exhaust composition fairly similar to diesel exhaust and is expected to be used to meet the 2007 and later heavy-duty highway diesel standards. As discussed in section III, application of this technology to nonroad diesels has some additional engineering challenges. In that section, we discuss the current status of this technology as well as the major development issues still to be addressed and the development steps that can be taken. With the lead-time available and the introduction of ultra low sulfur nonroad diesel fuel, we are confident the proposed application of this technology to nonroad diesels would proceed at a reasonable rate of progress and will result in systems capable of achieving the standards.

This view is further supported by the fact that manufacturers are already working on developing high-efficiency aftertreatment devices in order to have them available for introduction on highway diesel engines by 2007. EPA issued a progress report in June 2002 which discussed our findings that industry was making substantial progress in developing these devices. Additionally, the Clean Diesel Independent Review Panel issued a report in October 2002 on similar

[6] U.S. EPA (2002) Health Assessment Document for Diesel Engine Exhaust. EPA/600/8–90/057F Office of Research and Development, Washington DC. This document is available electronically at *http://cfpub.epa.gov/ncea/cfm/recordisplay.cfm?deid=29060.*

[7] For example, *see* letters dated April 9, 2002, from Agency Secretary of California EPA, Commissioner of NY State DEC, and Commissioner of Texas NRCC to Governor Whitman; dated January 28, 2003 from Western Regional Air Partnership to Governor Whitman, and dated December 17, 2002, from State and Territorial Air Pollution Program Administrators and Association of Local Air Pollution Control Officials and Northeast States for Coordinated Air Use Mangement (and other organizations).

questions and concluded that, while technical issues remain, there were no technical hurdles identified that would prevent market introduction of high-efficiency aftertreatment devices on schedule.

The need to reduce sulfur in nonroad diesel fuel is driven by the requirements of the exhaust emission control technology that we project will be needed to meet the proposed standards for most nonroad diesel engines. The challenge in accomplishing the sulfur reduction is driven by the capacity to implement the needed refinery modifications, and by the costs of making the modifications and running the equipment. Today, a number of refiners are acting to provide low sulfur diesel to some markets. We believe that controlling the sulfur content of highway diesel fuel to the 15 ppm level is necessary, feasible, and cost-effective.

Additionally, there are health and welfare benefits associated with the initial step of reducing the sulfur level of nonroad, locomotive, and marine diesel fuel to 500 ppm. This proposed action will provide dramatic, immediate reductions in direct sulfate PM and SO_2 emissions from the in-use fleet. As described in this proposal, we believe this fuel control strategy is a cost-effective air quality solution as well.

3. Basis for Action Under the Clean Air Act

Section 213 of the Act gives us the authority to establish emissions standards for nonroad engines and vehicles. Section 213(a)(3) authorizes the Administrator to set standards for NO_X, VOCs, or carbon monoxide, to reduce ambient levels of ozone and carbon monoxide which ''standards shall achieve the greatest degree of emission reduction achievable through the application of technology which the Administrator determines will be available for the engines or vehicles.'' As part of this determination, the Administrator must give appropriate consideration to cost, lead time, noise, energy, and safety factors associated with the application of such technology. Section 213(a)(4) authorizes the Administrator to establish standards to control emissions of pollutants which ''may reasonably be anticipated to endanger public health and welfare''. Here, the Administrator may promulgate regulations that are deemed appropriate for new nonroad vehicles and engines which cause or contribute to such air pollution, taking into account costs, noise, safety, and energy factors. EPA believes the proposed controls for PM in today's rule would be an appropriate exercise of EPA's discretion under the authority of section 213(a)(4).

We believe the evidence provided in section III and the Draft Regulatory Impact Analysis (RIA) indicates that the stringent emission standards proposed today are feasible and reflect the greatest degree of emission reduction achievable in the model years to which they apply. We have given appropriate consideration to costs in proposing these standards. Our review of the costs and cost-effectiveness of these standards indicate that they will be reasonable and comparable to the cost-effectiveness of other emission reduction strategies that have been required or could be required in the future. We have also reviewed and given appropriate consideration to the energy factors of this rule in terms of fuel efficiency and effects on diesel fuel supply, production, and distribution, as discussed below, as well as any safety factors associated with these proposed standards.

The information in section II and chapter 2 of the draft RIA regarding air quality and the contribution of nonroad, locomotive, and marine diesel engines to air pollution provides strong evidence that emissions from such engines significantly and adversely impact public health or welfare. First, as noted earlier, there is a significant risk that several areas will fail to attain or maintain compliance with the NAAQS for 8-hour ozone concentrations or for PM2.5 concentrations during the period that these new vehicle and engine standards will be phased into the vehicle population, and that nonroad, locomotive, and marine diesel engines contribute to such concentrations, as well as to concentrations of other NAAQS-related pollutants. This risk will be significantly reduced by the standards adopted today, as also noted above. However, the evidence indicates that some risk remains even after the reductions achieved by these new controls on nonroad diesel engines and nonroad, locomotive, and marine diesel fuel. Second, EPA believes that diesel exhaust is likely to be carcinogenic to humans. The risk associated with exposure to diesel exhaust includes the particulate and gaseous components among which are benzene, formaldehyde, acetaldehyde, acrolein, and 1,3-butadiene, all of which are known or suspected human or animal carcinogens, or have serious noncancer health effects. Third, emissions from nonroad diesel engines (including locomotive and marine diesel engines) contribute to regional haze and impaired visibility across the nation, as well as acid deposition, POM deposition, eutrophication and nitrification, all of which are serious environmental welfare problems.

EPA has already found in previous rules that emissions from new nonroad diesel engines contribute to ozone and carbon monoxide (CO) concentrations in more than one area which has failed to attain the ozone and carbon monoxide NAAQS. 59 FR 31306 (June 17, 1994). EPA has also previously determined that it is appropriate to establish standards for PM from new nonroad diesel engines under section 213(a)(4), and the additional information on diesel exhaust carcinogenicity noted above reinforces this finding. In addition, we have already found that emissions from nonroad engines significantly contribute to air pollution that may reasonably be anticipated to endanger public welfare due to regional haze and visibility impairment. 67 FR 68242, 68243 (Nov. 8, 2002). We find here, based on the information in section II of this preamble and chapter 2 of the draft RIA, that emissions from the new nonroad diesel engines covered by this proposal likewise contribute to regional haze and to visibility impairment that may reasonably be anticipated to endanger public welfare. Taken together, these findings indicate the appropriateness of the nonroad diesel engine standards proposed today for purposes of section 213(a)(3) and (4) of the Act.

Section 211(c) of the CAA allows us to regulate fuels where emission products of the fuel either: (1) Cause or contribute to air pollution that reasonably may be anticipated to endanger public health or welfare, or (2) will impair to a significant degree the performance of any emission control device or system which is in general use, or which the Administrator finds has been developed to a point where in a reasonable time it will be in general use were such a regulation to be promulgated. This rule meets both of these criteria. SOx and sulfate PM emissions from nonroad, locomotive, marine and diesel vehicles are due to sulfur in diesel fuel. As discussed above, emissions of these pollutants cause or contribute to ambient levels of air pollution that endanger public health and welfare. Control of sulfur to 500 ppm for this fuel would lead to significant, cost-effective reductions in emissions of these pollutants. The substantial adverse effect of high sulfur levels on the performance of diesel emission control devices or systems that would be expected to be used to meet the nonroad standards is discussed in detail in section III. Control of sulfur to 15 ppm in nonroad diesel fuel would enable emissions control technology that will achieve significant, cost-effective reduction in emissions of these pollutants, as discussed in section II below. In addition, our authority under section 211(c) is discussed in more detail in Appendix A to the draft RIA.

II. What Is the Air Quality Impact of the Sources Covered by the Proposed Rule?

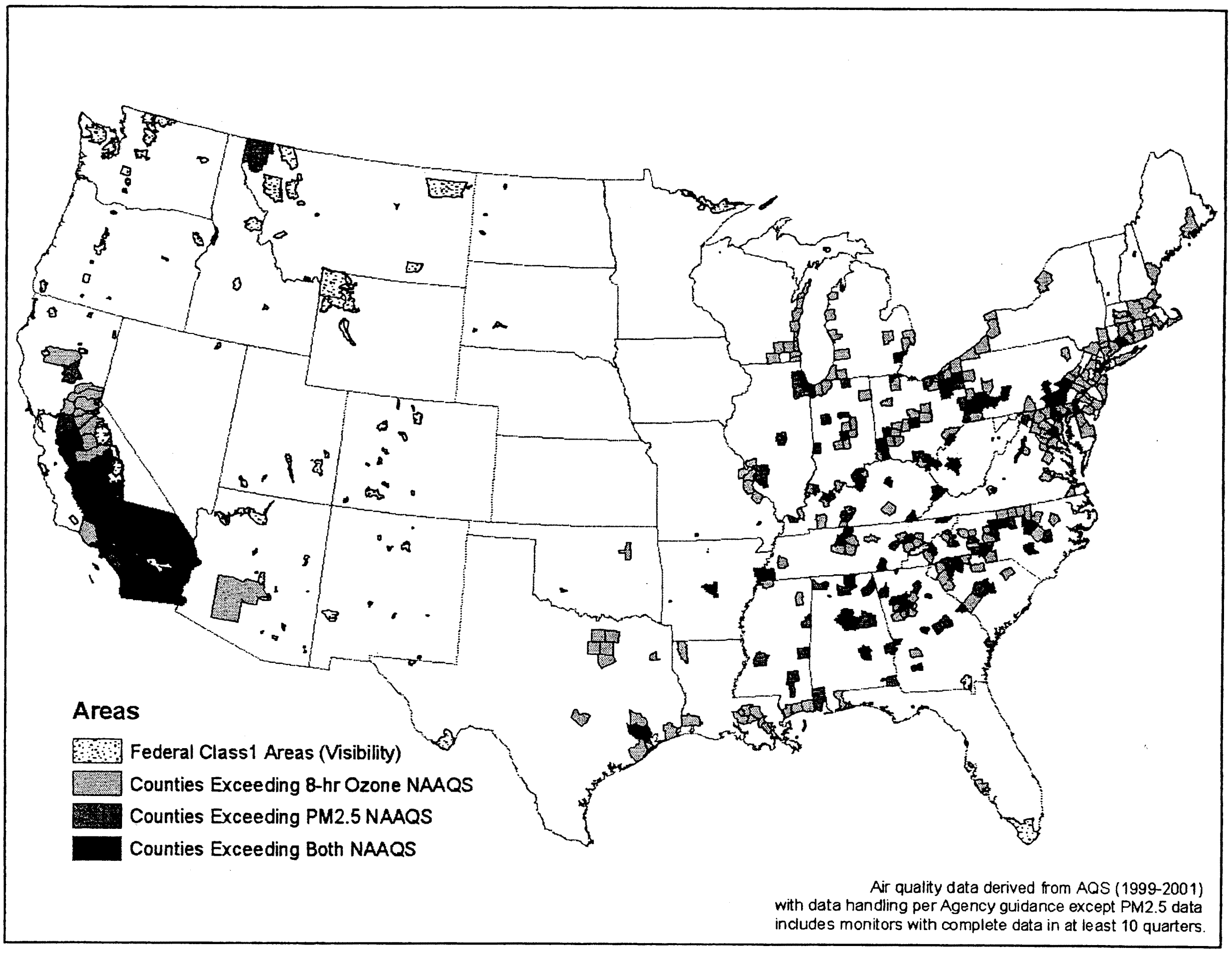
With this proposal, EPA is acting to extend highway types of emission controls to another major source of diesel engine emissions, nonroad diesel engines. These emissions are significant contributors to atmospheric pollution from particulate matter, ozone and a variety of toxic air pollutants. In our most recent nationwide inventory used for this proposal (1996), the nonroad diesels affected by this proposal [8] contribute over 43 percent of diesel PM emissions from mobile sources, up to 18 percent of $PM_{2.5}$ emissions in urban areas, and up to 14 percent of NO_X emissions in urban areas.

Without further control beyond those standards we have already adopted, by the year 2020, these engines will emit 62 percent of diesel PM emissions from mobile sources, up to 19 percent of $PM_{2.5}$ emissions in urban areas, and up to 20 percent of NO_X emissions in urban areas.

When fully implemented, this proposal would reduce nonroad diesel $PM_{2.5}$ and NO_X emissions by more than 90 percent. It will also virtually eliminate nonroad diesel SO_x emissions, which amounted to nearly 230,000 tons in 1996, and would otherwise grow to approximately 340,000 tons by 2020.

These dramatic reductions in nonroad emissions are a critical part of the effort by Federal, State and local governments to reduce the health-related impacts of air pollution and to reach attainment of the NAAQS for PM and ozone, as well as to improve other environmental effects such as atmospheric visibility. Based on the most recent data available for this rule (1999–2001), such problems are widespread in the United States. There are over 65 million people living in counties with monitored $PM_{2.5}$ levels exceeding the $PM_{2.5}$ NAAQS, and 111 million people living in counties with monitored concentrations exceeding the 8-hour ozone NAAQS. Figure II.–1 illustrates the widespread nature of these problems. Shown in this figure are counties exceeding either or both of the two NAAQS plus mandatory Federal Class I areas, which have particular needs for reductions in atmospheric haze.

FIGURE II-1 -- AIR QUALITY PROBLEMS ARE WIDESPREAD



As we will describe later in this preamble, the air quality improvements expected from this proposal is anticipated to produce major benefits to human health and welfare, with a combined value in excess of half a

[8] For NO_X and $PM_{2.5}$ this includes all land-based nonroad diesel engines, but not locomotive, commercial marine vessel, and recreational marine vessel engines. Since the latter three engine categories are affected by the fuel sulfur portions of the proposal, they are included for SO_2.

trillion dollars between 2007 and 2030. By the year 2030, this proposed rule would be expected to prevent approximately 9,600 deaths per year from premature mortality, and 16,000 nonfatal heart attacks. It is estimated to also prevent 14,000 acute bronchitis attacks in children, 260,000 respiratory symptoms in children, and nearly 1 million lost work days in 2030. The reductions will also improve visibility.

In the remainder of this section we will describe in more detail the air pollution problems associated with emissions from nonroad diesel engines, and the emission and air quality benefits we expect to realize from the fuel and engine controls in this proposal.

A. Overview

The emissions from nonroad engines that are being directly controlled by the standards in this rulemaking are NO_X, PM and NMHC, and to a lesser extent, CO. Gaseous air toxics from nonroad diesels will also be reduced as a consequence of the proposed standards. In addition there will be a substantial reduction in SO_x emissions resulting from the proposed reduction in sulfur level in diesel fuel.

From a public health perspective, we are primarily concerned with nonroad engine contributions to atmospheric levels of particulate matter in general, diesel PM in particular and various gaseous air toxics emitted by diesel engines, and ozone.[9] We will first review important public health effects linked to these pollutants, briefly describing the human health effects and the current and expected future ambient levels of direct or indirectly caused pollution. Our presentation will show that substantial further reductions of these pollutants, and the underlying emissions from nonroad diesel engines, are needed to protect public health.

Following discussion of health effects, we will discuss a number of welfare effects associated with emissions from diesel engines. These effects include atmospheric visibility impairment, ecological and property damage caused by acid deposition, eutrophication and nitrification of surface waters, environmental threats posed by polycyclic organic matter (POM) deposition, and plant and crop damage from ozone. Once again, the information available to us indicates a continuing need for further nonroad emission reductions to bring about improvements in air quality.

Next, we will describe our understanding of the engine emission inventories for the primary pollutants affected by the proposal. As noted above, these include PM, NO_X, SO_X, Air Toxics and HC. We will present current and projected future levels of emissions for the base case, including anticipated reductions from control programs already adopted by EPA and the States, but without the controls proposed today. Then we will identify expected emission reductions from nonroad engines. These reductions will make important contributions to controlling the health and welfare problems associated with ambient PM and ozone levels and with diesel related air toxics.

While the material we will present in this section will describe our understanding of the need for control of nonroad engine emissions and the air quality improvements we expect to realize, this section is not an exhaustive treatment of these issues. For a fuller understanding of the topics treated here, you should refer to the extended presentations in the Draft Regulatory Impact Analysis accompanying this proposal.

B. Public Health Impacts

1. Particulate Matter

Particulate matter (PM) represents a broad class of chemically and physically diverse substances. It can be principally characterized as discrete particles that exist in the condensed (liquid or solid) phase spanning several orders of magnitude in size. PM_{10} refers to particles with an aerodynamic diameter less than or equal to a nominal 10 micrometers. Fine particles refer to those particles with an aerodynamic diameter less than or equal to a nominal 2.5 micrometers (also known as $PM_{2.5}$), and coarse fraction particles are those particles with an aerodynamic diameter greater than 2.5 microns, but less than or equal to a nominal 10 micrometers. Ultrafine PM refers to particles with diameters of less than 100 nanometers (0.1 micrometers). The health and environmental effects of PM are associated with fine PM fraction and, in some cases, to the size of the particles. Specifically, larger particles (>10 µm) tend to be removed by the respiratory clearance mechanisms whereas smaller particles are deposited deeper in the lungs. Also, particles scatter light obstructing visibility.

The emission sources, formation processes, chemical composition, atmospheric residence times, transport distances and other parameters of fine and coarse particles are distinct. Fine particles are directly emitted from combustion sources and are formed secondarily from gaseous precursors such as sulfur dioxide (SO_X), oxides of nitrogen (NO_X), or organic compounds. Fine particles are generally composed of sulfate, nitrate, chloride, ammonium compounds, organic carbon, elemental carbon, and metals. Nonroad diesels currently emit high levels of NO_X which react in the atmosphere to form secondary $PM_{2.5}$ (namely ammonium nitrate). Nonroad diesel engines also emit SO_2 and HC which react in the atmosphere to form secondary $PM_{2.5}$ (namely sulfates and organic carbonaceous $PM_{2.5}$). Combustion of coal, oil, diesel, gasoline, and wood, as well as high temperature process sources such as smelters and steel mills, produce emissions that contribute to fine particle formation. In contrast, coarse particles are typically mechanically generated by crushing or grinding. They include resuspended dusts and crustal material from paved roads, unpaved roads, construction, farming, and mining activities. These coarse particles can be either natural in source such as road dust or anthropogenic. Fine particles can remain in the atmosphere for days to weeks and travel through the atmosphere hundreds to thousands of kilometers, while coarse particles deposit to the earth within minutes to hours and within tens of kilometers from the emission source.

The relative contribution of various chemical components to $PM_{2.5}$ varies by region of the country. Data on $PM_{2.5}$ composition are available from the EPA Speciation Trends Network in 2001 and the *I*nteragency *M*onitoring of *PRO*tected *V*isual *E*nvironments (IMPROVE) network in 1999 covering both urban and rural areas in numerous regions of the U.S. These data show that carbonaceous $PM_{2.5}$ makes up the major component for $PM_{2.5}$ in both urban and rural areas in the western U.S. Carbonaceous $PM_{2.5}$ includes both elemental and organic carbon. Nitrates formed from NO_X also play a major role in the western U.S., especially in the California area where it is responsible for about a quarter of the ambient $PM_{2.5}$ concentrations. Sulfate plays a lesser role in these regions. For the eastern and mid U.S., these data show that both sulfates and carbonaceous $PM_{2.5}$ are major contributors to ambient $PM_{2.5}$ in both urban and rural areas. In some eastern areas, carbonaceous $PM_{2.5}$ is responsible for up to half of ambient $PM_{2.5}$ concentrations. Sulfate is also a

[9] Ambient particulate matter from nonroad diesel engine is associated with the direct emission of diesel particulate matter, and with particulate matter formed indirectly in the atmosphere by NO_X and SO_x emissions (and to a lesser extent NMHC emissions). Both NO_X and NMHC participate in the atmospheric chemical reactions that produce ozone.

major contributor to ambient $PM_{2.5}$ in the eastern U.S. and in some areas make greater contributions than carbonaceous $PM_{2.5}$[10][11]

Nonroad engines, and most importantly nonroad diesel engines, contribute significantly to ambient $PM_{2.5}$ levels, largely through emissions of carbonaceous $PM_{2.5}$. Carbonaceous $PM_{2.5}$ is a major portion of ambient $PM_{2.5}$, especially in populous urban areas. Nonroad diesels also emit high levels of NO_X which react in the atmosphere to form secondary $PM_{2.5}$ (namely nitrate). Nonroad diesels also emit SO_2 and NMHC which react in the atmosphere to form secondary $PM_{2.5}$ (namely sulfates and organic carbonaceous $PM_{2.5}$). For more details, consult the draft RIA for this proposed rule.

Diesel particles from nonroad diesel are a component of both coarse and fine PM, but fall mainly in the fine (and even ultrafine) size range. As discussed later, diesel PM also contains small quantities of numerous mutagenic and carcinogenic compounds associated with the particulate (and also organic gases). In addition, while toxic trace metals emitted by nonroad diesel engines represent a very small portion of the national emissions of metals (less than one percent) and a small portion of diesel PM (generally less than one percent of diesel PM), we note that several trace metals of potential toxicological significance and persistence in the environment are emitted by diesel engines. These trace metals include chromium, manganese, mercury and nickel. In addition, small amounts of dioxins have been measured in highway engine diesel exhaust, some of which may partition into the particulate phase; dioxins through out the environment are a major health concern (although the diesel contribution has not been judged significant at this point). Diesel engines also emit polycyclic organic matter (POM), including polycyclic aromatic hydrocarbons (PAH), which can be present in both gas and particle phases of diesel exhaust. Many PAH compounds are classified by EPA as probable human carcinogens.

For additional, detailed, information on PM beyond that summarized below, see the draft Regulatory Impact Analysis.

a. Health Effects of $PM_{2.5}$ and PM_{10}

Scientific studies show ambient PM (which is attributable to a number of sources, including nonroad diesel) is associated with a series of adverse health effects. These health effects are discussed in detail in the EPA Criteria Document for PM as well as the draft updates of this document released in the past year.[12][13] In addition, EPA's final ''Health Assessment Document for Diesel Engine Exhaust,'' (the Diesel HAD) also reviews health effects information related to diesel exhaust as a whole including diesel PM, which is one component of ambient PM.[14]

As described in these documents, health effects associated with short-term variation in ambient particulate matter (PM) have been indicated by epidemiologic studies showing associations between exposure and increased hospital admissions for ischemic heart disease, heart failure, respiratory disease, including chronic obstructive pulmonary disease (COPD) and pneumonia. Short-term elevations in ambient PM have also been associated with increased cough, lower respiratory symptoms, and decrements in lung function. Short-term variations in ambient PM have also been associated with increases in total and cardiorespiratory daily mortality. Studies examining populations exposed to different levels of air pollution over a number of years, including the Harvard Six Cities Study and the American Cancer Society Study suggest an association between exposure to ambient $PM_{2.5}$ and premature mortality, including deaths attributed to lung cancer.[15][16] Two studies further analyzing the Harvard Six Cities Study's air quality data have also established a specific influence of mobile source-related $PM_{2.5}$ on daily mortality[17] and a concentration-response function for mobile source-associated $PM_{2.5}$ and daily mortality.[18] Another recent study in 14 U.S. cities examining the effect of PM_{10} on daily hospital admissions for cardiovascular disease found that the effect of PM_{10} was significantly greater in areas with a larger proportion of PM_{10} coming from motor vehicles, indicating that PM_{10} from these sources may have a greater effect on the toxicity of ambient PM_{10} when compared with other sources.[19] Additional studies have associated changes in heart rate and/or heart rhythm in addition to changes in blood characteristics with exposure to ambient PM.[20][21] For additional information on health effects, see the draft RIA.

The health effects of PM_{10} are similar to those of $PM_{2.5}$, since PM_{10} includes all of $PM_{2.5}$ plus the coarse fraction from 2.5 to 10 micrometers in size. EPA is also evaluating the health effects of PM between 2.5 and 10 micrometers in the draft revised Criteria Document. As discussed in the Diesel HAD and other studies, most diesel PM is smaller than 2.5 micrometers.[22] Both fine and coarse fraction particles can enter and deposit in the respiratory system.

In addition to the information in the draft revised Criteria Document, the relevance of health effects associated with on-road diesel engine-generated PM to nonroad applications is supported by the observation in the Diesel HAD that the particulate characteristics in the zone around nonroad diesel engines is likely to be substantially the same as published air quality measurements made along busy roadways.

Of particular relevance to this rule is a recent cohort study which examined the association between mortality and

[10] Rao, Venkatesh; Frank, N.; Rush, A.; and Dimmick, F. (November 13–15, 2002). Chemical speciation of $PM_{2.5}$ in urban and rural areas (November 13–15, 2002) In the Proceedings of the Air & Waste Management Association Symposium on Air Quality Measurement Methods and Technology, San Francisco Meeting.

[11] EPA (2002) Latest Finds on National Air Quality, EPA 454/K–02–001.

[12] U.S. EPA (1996.) Air Quality Criteria for Particulate Matter—Volumes I, II, and III, EPA, Office of Research and Development. Report No. EPA/600/P–95/001a–cF. This material is available electronically at *http://www.epa.gov/ttn/oarpg/ticd.html.*

[13] U.S. EPA (2002). Air Quality Criteria for Particulate Matter—Volumes I and II (Third External Review Draft) This material is available electronically at *http://cfpub.epa.gov/ncea/cfm/partmatt.cfm.*

[14] U.S. EPA (2002). Health Assessment Document for Diesel Engine Exhaust. EPA/600/8–90/057F Office of Research and Development, Washington DC. This document is available electronically at *http://cfpub.epa.gov/ncea/cfm/recordisplay.cfm?deid=29060.*

[15] Dockery, DW; Pope, CA, III; Xu, X; *et al.* (1993) An association between air pollution and mortality in six U.S. cities. N Engl J Med 329:1753–1759.

[16] Pope, CA, III; Thun, MJ; Namboordiri, MM; *et al.* (1995) Particulate air pollution as a predictor of mortality in a prospective study of U.S. adults. Am J Respir Crit Care Med 151:669–674.

[17] Laden F; Neas LM; Dockery DW; *et al.* (2000) Association of fine particulate matter from different sources with daily mortality in six U.S. cities. Environ Health Perspect 108(10):941–947.

[18] Schwartz J; Laden F; Zanobetti A. (2002) The concentration-response relation between PM(2.5) and daily deaths. Environ Health Perspect 110(10): 1025–1029.

[19] Janssen NA; Schwartz J; Zanobetti A.; *et al.* (2002) Air conditioning and source-specific particles as modifiers of the effect of PM_{10} on hospital admissions for heart and lung disease. Environ Health Perspect 110(1):43–49.

[20] Pope CA III, Verrier RL, Lovett EG; *et al.* (1999) Heart rate variability associated with particulate air pollution. Am Heart J 138(5 Pt 1):890–899.

[21] Magari SR, Hauser R, Schwartz J; *et al.* (2001) Association of heart rate variability with occupational and environmental exposure to particulate air pollution. Circulation 104(9):986–991.

[22] U.S. EPA (1985). Size specific total particulate emission factor for mobile sources. EPA 460/3–85–005. Office of Mobile Sources, Ann Arbor, MI.

residential proximity to major roads in the Netherlands. Examining a cohort of 55 to 69 year-olds from 1986 to1994, the study indicated that long-term residence near major roads, an index of exposure to primary mobile source emissions (including diesel exhaust), was significantly associated with increased cardiopulmonary mortality.[23] Other studies have shown children living near roads with high truck traffic density have decreased lung function and greater prevalence of lower respiratory symptoms compared to children living on other roads.[24] A recent review of epidemiologic studies examining associations between asthma and roadway proximity concluded that some coherence was evident in the literature, indicating that asthma, lung function decrement, respiratory symptoms, and other respiratory problems appear to occur more frequently in people living near busy roads.[25] As discussed later, nonroad diesel engine emissions, especially particulate, are similar in composition to those from highway diesel vehicles. Although difficult to associate directly with $PM_{2.5}$, these studies indicate that direct emissions from mobile sources, and diesel engines specifically, may explain a portion of respiratory health effects observed in larger-scale epidemiologic studies. Recent studies conducted in Los Angeles have illustrated that a substantial increase in the concentration of ultrafine particles is evident in locations near roadways, indicating substantial differences in the nature of PM immediately near mobile source emissions.[26]

Also, as discussed in more detail later, in addition to its contribution to ambient PM inventories, diesel PM is of special concern because diesel exhaust has been associated with an increased risk of lung cancer. As also discussed later in more detail, we concluded that diesel exhaust ranks with other substances that the national-scale air toxics assessment suggests pose the greatest relative risk.

b. Current and Projected Levels

There are NAAQS for both PM_{10} and $PM_{2.5}$. Violations of the annual $PM_{2.5}$ standard are much more widespread than are violations of the PM_{10} standards. Emission reductions needed to attain the $PM_{2.5}$ standards will also assist in attaining and maintaining compliance with the PM_{10} standards. Thus, since most PM emitted by diesel nonroad engines is fine PM, the emission controls proposed today should contribute to attainment and maintenance of the existing PM NAAQS. More broadly, the proposed standards will benefit public health and welfare through reductions in direct diesel PM and reductions of NO_X, SO_X, and NMHCs which contribute to secondary formation of PM. The reductions from these proposed rules will assist States as they implement local controls as needed to help their areas attain and maintain the standards.

i. PM_{10} Levels

The current NAAQS for PM_{10} were established in 1987. The primary (health-based) and secondary (public welfare based) standards for PM_{10} include both short- and long-term NAAQS. The short-term (24 hour) standard of 150 ug/m^3 is not to be exceeded more than once per year on average over three years. The long-term standard specifies an expected annual arithmetic mean not to exceed 50 ug/m^3 averaged over three years.

Currently, 29 million people live in PM_{10} nonattainment areas. There are currently 58 moderate PM_{10} nonattainment areas with a total population of 6.8 million. The attainment date for the initial moderate PM_{10} nonattainment areas, designated by operation of law on November 15, 1990, was December 31, 1994. Several additional PM_{10} nonattainment areas were designated on January 21, 1994, and the attainment date for these areas was December 31, 2000. There are an additional 8 serious PM_{10} nonattainment areas with a total affected population of 22.7 million. According to the Act, serious PM_{10} nonattainment areas must attain the standards no later than 10 years after designation. The initial serious PM_{10} nonattainment areas were designated January 18, 1994, and had an attainment date set by the Act of December 31, 2001. The Act provides that EPA may grant extensions of the serious area attainment dates of up to 5 years, provided that the area requesting the extension meets the requirements of section 188(e) of the Act. Four serious PM_{10} nonattainment areas (Phoenix, Arizona; Coachella Valley, South Coast (Los Angeles), and Owens Valley, California) have received extensions of the December 31, 2001, attainment date and thus have new attainment dates of December 31, 2006.[27] While all of these areas are expected to be in attainment before the emission reductions from this proposed rule are expected to occur, these reductions will be important to assist these areas in maintaining the standards.

ii. $PM_{2.5}$ Levels

The need for reductions in the levels of $PM_{2.5}$ is widespread. Figure II–1 at the beginning of this air quality section highlighted monitor locations measuring concentrations above the level of the NAAQS. As can be seen from that figure, high ambient levels are widespread throughout the country.

The NAAQS for $PM_{2.5}$ were established by EPA in 1997 (62 FR 38651, July 18, 1997). The short term (24-hour) standard is set at a level of 65 $\mu g/m_3$ based on the 98th percentile concentration averaged over three years. (This air quality statistic compared to the standard is referred to as the ''design value.'') The long-term standard specifies an expected annual arithmetic mean not to exceed 15 ug/m^3 averaged over three years.

Current $PM_{2.5}$ monitored values for 1999–2001, which cover counties having about 75 percent of the country's population, indicate that at least 65 million people in 129 counties live in areas where annual design values of ambient fine PM violate the $PM_{2.5}$ NAAQS. There are an additional 9 million people in 20 counties where levels above the NAAQS are being measured, but there are insufficient data at this time to calculate a design value in accordance with the standard, and thus determine whether these areas are violating the $PM_{2.5}$ NAAQS. In total, this represents 37 percent of the counties and 64 percent of the population in the areas with monitors with levels above the NAAQS. Furthermore, an additional 14 million people live in 41 counties that have air quality measurements within 10 percent of the level of the standard. These areas, although not currently violating the standard, will also benefit from the additional reductions from this rule in order to ensure long term maintenance.

Our air quality modeling performed for this proposal also indicates that similar conditions are likely to continue

[23] Hoek, G; Brunekreef, B; Goldbohm, S; *et al.* (2002) Association between mortality and indicators of traffic-related air pollution in the Netherlands: a cohort study. Lancet 360(9341): 1203–1209.

[24] Brunekreef, B; Janssen NA; de Hartog, J; *et al.* (1997) Air pollution from traffic and lung function in children living near motor ways. Epidemiology (8): 298–303.

[25] Delfino RJ. (2002) Epidemiologic evidence for asthma and exposure to air toxics: linkages between occupational, indoor, and community air pollution research. Env Health Perspect Suppl 110(4): 573–589.

[26] Yifang Zhu, William C. Hinds, Seongheon Kim, Si Shen and Constantinos Sioutas Zhu Y; Hinds WC; Kim S; *et al.* (2002) Study of ultrafine particles near a major highway with heavy-duty diesel traffic. Atmos Environ 36(27): 4323–4335.

[27] EPA has also proposed to grant Las Vegas, Nevada, an extension until December 31, 2006.

to exist in the future in the absence of additional controls. For example, in 2020 based on emission controls currently adopted, we project that 66 million people will live in 79 counties with average $PM_{2.5}$ levels above 15 ug/m^3. In 2030, the number of people projected to live in areas exceeding the $PM_{2.5}$ standard is expected to increase to 85 million in 107 counties. An additional 24 million people are projected to live in counties within 10 percent of the standard in 2020, which will increase to 64 million people in 2030.

Our modeling also indicates that the reductions we are expecting will make a substantial contribution to reducing exposures in these areas.[28] In 2020, the number of people living in counties with $PM_{2.5}$ levels above the NAAQS would be reduced from 66 million to 60 million living in 67 counties, which reflects a reduction of 9 percent in potentially exposed population and 15 percent of the number of counties. In 2030, there would be a reduction from 85 million people to 71 million living in 84 counties. These represent even greater improvements than projected for 2020 (numbers of people potentially exposed down 16 percent and number of counties down 21 percent). Furthermore, our modeling also shows that the emission reductions would assist areas with future maintenance of the standards.

We estimate that the reduction of PM levels expected from this proposed rule would produce nationwide air quality improvements in PM levels. On a population weighted basis, the average change in future year annual averages would be a decrease of 0.33 ug/m^3 in 2020, and 0.46 ug/m^3 in 2030. The reductions are discussed in more detail in chapter 2 of the draft RIA.

While the final implementation process for bringing the nation's air into attainment with the $PM_{2.5}$ NAAQS is still being completed in a separate rulemaking action, the basic framework is well defined by the statute. EPA's current plans call for designating $PM_{2.5}$ nonattainment areas in late-2004. Following designation, Section 172(b) of the Clean Air Act allows states up to three years to submit a revision to their state implementation plan (SIP) that provides for the attainment of the $PM_{2.5}$ standard. Based on this provision, states could submit these SIPs as late as the end of 2007. Section 172(a)(2) of the Clean Air Act requires that these SIP revisions demonstrate that the nonattainment areas will attain the $PM_{2.5}$ standard as expeditiously as practicable but no later than five years from the date that the area was designated nonattainment. However, based on the severity of the air quality problem and the availability and feasibility of control measures, the Administrator may extend the attainment date ''for a period of no greater than 10 years from the date of designation as nonattainment.'' Therefore, based on this information, we expect that most or all areas will need to attain the $PM_{2.5}$ NAAQS in the 2009 to 2014 time frame, and then be required to maintain the NAAQS thereafter.

Since the emission reductions expected from this proposal would begin in this same time frame, the projected reductions in nonroad emissions would be used by states in meeting the $PM_{2.5}$ NAAQS. States and state organizations have told EPA that they need nonroad diesel engine reductions in order to be able to meet and maintain the $PM_{2.5}$ NAAQS as well as visibility regulations, especially in light of the otherwise increasing emissions from nonroad sources without more stringent standards.[29] [30] [31] Furthermore, this action would ensure that nonroad diesel emissions will continue to decrease as the fleet turns over in the years beyond 2014; these reductions will be important for maintenance of the NAAQS following attainment. The future reductions are also important to achieve visibility goals, as discussed later.

2. Air Toxics

a. Diesel Exhaust

A number of health studies have been conducted regarding diesel exhaust including epidemiologic studies of lung cancer in groups of workers, and animal studies focusing on non-cancer effects specific to diesel exhaust. Diesel exhaust PM (including the associated organic compounds which are generally high molecular weight hydrocarbon types but not the more volatile gaseous hydrocarbon compounds) is generally used as a surrogate measure for diesel exhaust.

i. Potential Cancer Effects of Diesel Exhaust

In addition to its contribution to ambient PM inventories, diesel exhaust is of specific concern because it has been judged to pose a lung cancer hazard for humans as well as a hazard from noncancer respiratory effects.

EPA recently released its ''Health Assessment Document for Diesel Engine Exhaust,'' (the Diesel HAD).[32] There, diesel exhaust was classified as likely to be carcinogenic to humans by inhalation at environmental exposures, in accordance with the revised draft 1996/1999 EPA cancer guidelines. A number of other agencies (National Institute for Occupational Safety and Health, the International Agency for Research on Cancer, the World Health Organization, California EPA, and the U.S. Department of Health and Human Services) have made similar classifications. It should be noted that the conclusions in the Diesel HAD were based on diesel engines currently in use, including nonroad diesel engines such as those found in bulldozers, graders, excavators, farm tractor drivers and heavy construction equipment. As new diesel engines with significantly cleaner exhaust emissions replace existing engines, the conclusions of the Diesel HAD will need to be reevaluated.

For the EPA Diesel HAD, EPA reviewed 22 epidemiologic studies in detail, finding increased lung cancer risk in 8 out of 10 cohort studies and 10 out of 12 case-control studies. Relative risk for lung cancer associated with exposure range from 1.2 to 2.6. In addition, two meta-analyses of occupational studies of diesel exhaust and lung cancer have estimated the smoking-adjusted relative risk of 1.35 and 1.47, examining 23 and 30 studies, respectively.[33] [34] That is, these two studies show an overall increase in lung cancer for the exposed groups of 35 percent and 47 percent compared to the groups not exposed to diesel exhaust. In the EPA Diesel HAD, EPA selected 1.4

[28] The results illustrate the type of PM changes for the preliminary control option, as discussed in the Draft RIA in section 3.6. The proposal differs from the modeled control case based on updated information; however, we believe that the net results would approximate future emissions, although we anticipate the PM reductions might be slightly smaller.

[29] California Air Resources Board and New York State Department of Environmental Conservation (April 9, 2002), Letter to EPA Administrator Christine Todd Whitman.

[30] State and Territorial Air Pollution Program Administrators (STAPPA) and Association of Local Air Pollution Control Officials (ALAPCO) (December 17, 2002), Letter to EPA Assistant Administrator Jeffrey R. Holmstead.

[31] Western Regional Air Partnership (WRAP) (January 28, 2003), Letter to Governor Christine Todd Whitman.

[32] U.S. EPA (2002). Health Assessment Document for Diesel Engine Exhaust. EPA/600/8–90/057F Office of Research and Development, Washington DC. This document is available electronically at *http://cfpub.epa.gov/ncea/cfm/recordisplay.cfm?deid=29060.*

[33] Bhatia, R., Lopipero, P., Smith, A. (1998). Diesel exhaust exposure and lung cancer. Epidemiology 9(1):84–91.

[34] Lipsett, M: Campleman, S.; (1999). Occupational exposure to diesel exhaust and lung cancer: a meta-analysis. Am J Public Health 80(7):1009–1017.

as a reasonable estimate of occupational relative risk for further analysis.

EPA generally derives cancer unit risk estimates to calculate population risk more precisely from exposure to carcinogens. In the simplest terms, the cancer unit risk is the increased risk associated with average lifetime exposure of 1 ug/m^3. EPA concluded in the Diesel HAD that it is not possible currently to calculate a cancer unit risk for diesel exhaust due to a variety of factors that limit the current studies, such as a lack of standard exposure metric for diesel exhaust and the absence of quantitative exposure characterization in retrospective studies.

EPA generally derives cancer unit risk estimates to calculate population risk more precisely from exposure to carcinogens. In the simplest terms, the cancer unit risk is the increased risk associated with average lifetime exposure of 1 ug/m^3. EPA concluded in the Diesel HAD that it is not possible currently to calculate a cancer unit risk for diesel exhaust due to a variety of factors that limit the current studies, such as lack of an adequate dose-response relationship between exposure and cancer incidence.

However, in the absence of a cancer unit risk, the EPA Diesel HAD sought to provide additional insight into the possible ranges of risk that might be present in the population. Such insights, while not confident or definitive, nevertheless contribute to an understanding of the possible public health significance of the lung cancer hazard. The possible risk range analysis was developed by comparing a typical environmental exposure level to a selected range of occupational exposure levels and then proportionally scaling the occupationally observed risks according to the exposure ratio's to obtain an estimate of the possible environmental risk. If the occupational and environmental exposures are similar, the environmental risk would approach the risk seen in the occupational studies whereas a much higher occupational exposure indicates that the environmental risk is lower than the occupational risk. A comparison of environmental and occupational exposures showed that for certain occupations the exposures are similar to environmental exposures while, for others, they differ by a factor of about 200 or more.

The first step in this process is to note that the occupational relative risk of 1.4, or a 40 percent from increased risk compared to the typical 5 percent lung cancer risk in the U.S. population, translates to an increased risk of 2 percent (or 10^{-2}) for these diesel exhaust exposed workers. The Diesel HAD derived a typical nationwide average environmental exposure level of 0.8 ug./m^3 for diesel PM from highway sources for 1996. Diesel PM is a surrogate for diesel exhaust and, as mentioned above, has been classified as a carcinogen by some agencies.

This estimate was based on national exposure modeling; the derivation of this exposure is discussed in detail in the EPA Diesel HAD. The possible risk range in the environment was estimated by taking the relative risks in the occupational setting, EPA selected 1.4 and converting this to absolute risk of 2% and then ratioing this risk by differences in the occupational vs environmental exposures of interest. A number of calculations are needed to accomplish this, and these can be seen in the EPA Diesel HAD. The outcome was that environmental risks from diesel exhaust exposure could range from a low of 10^{-4} to 10^{-5} or be as high as 10^{-3} this being a reflection of the range of occupational exposures that could be associated with the relative and absolute risk levels observed in the occupational studies.

While these risk estimates are exploratory and not intended to provide a definitive characterization of cancer risk, they are useful in gauging the possible range of risk based on reasonable judgement. It is important to note that the possible risks could also be higher or lower and a zero risk cannot be ruled out. Some individuals in the population may have a high tolerance to exposure from diesel exhaust and low cancer susceptibility. Also, one cannot rule out the possibility of a threshold of exposure below which there is no cancer risk, although evidence has not been seen or substantiated on this point.

Also, as discussed in the Diesel HAD, there is a relatively small difference between some occupational settings where increased lung cancer risk is reported and ambient environmental exposures. The potential for small exposure differences underscores the appropriateness of the extrapolation from occupational risk to ambient environmental exposure levels is reasonable and appropriate.

EPA also recently completed an assessment of air toxic emissions (the National-Scale Air Toxics Assessment or NATA) and their associated risk, and we concluded that diesel exhaust ranks with other substances that the national-scale assessment suggests pose the greatest relative risk.[35] This assessment estimates average population inhalation exposures to diesel PM in 1996 for nonroad as well as on-road sources. These are the sum of ambient levels in various locations weighted by the amount of time people spend in each of the locations. This analysis shows a somewhat higher diesel exposure level than the 0.8 ug/m^3 used to develop the risk perspective in the Diesel HAD. The NATA levels are 1.4 ug/m^3 total with an on-road source contribution of 0.5 ug/m^3 to average nationwide exposure in 1996 and a nonroad source contribution of 0.9 ug/m^3. The average urban exposure concentration was 1.6 ug/m^3 and the average rural concentration was 0.55 ug/m^3. In five percent of urban census tracts across the United States, average concentrations were above 4.3 ug/m^3. The Diesel HAD states that use of the NATA exposure number results instead of the 0.8 ug/m^3 results in a similar risk perspective.

In 2001, EPA completed a rulemaking on mobile source air toxics with a determination that diesel particulate matter and diesel exhaust organic gases be identified as a Mobile Source Air Toxic (MSAT).[36] This determination was based on a draft of the Diesel HAD on which the Clean Air Scientific Advisory Committee of the Science Advisory Board had reached closure. The purpose of the MSAT list is to provide a screening tool that identifies compounds emitted from motor vehicles or their fuels for which further evaluation of emissions controls is appropriate.

In summary, even though EPA does not have a specific carcinogenic potency with which to accurately estimate the carcinogenic impact of diesel PM, the likely hazard to humans at environmental exposure levels leads us to conclude that diesel exhaust emissions of PM and organic gases should be reduced from nonroad engines in order to protect public health.

ii. Other Health Effects of Diesel Exhaust

The acute and chronic exposure-related effects of diesel exhaust emissions are also of concern to the Agency. The Diesel HAD established an inhalation Reference Concentration (RfC) specifically based on animal studies of diesel exhaust. An RfC is defined by EPA as ''an estimate of a continuous inhalation exposure to the human population, including sensitive subgroups, with uncertainty spanning

[35] U.S. EPA (2002). National-Scale Air Toxics Assessment. This material is available electronically at *http://www.epa.gov/ttn/atw/nata/*.

[36] U.S. EPA (2001). Control of Emissions of Hazardous Air Pollutants from Mobile Sources; Final Rule. 66 FR 17230–17273 (March 29, 2001).

perhaps an order of magnitude, that is likely to be without appreciable risks of deleterious noncancer effects during a lifetime.'' EPA derived the RfC from consideration of four chronic rat inhalation studies showing adverse pulmonary effects. The diesel RfC is based on a ''no observable adverse effect'' level of 144 ug/m^3 that is further reduced by applying uncertainty factors of 3 for interspecies extrapolation and 10 for human variations in sensitivity. The resulting RfC derived in the Diesel HAD is 5 ug/m^3 for diesel exhaust as measured by diesel PM. This RfC does not consider allergenic effects such as those associated with asthma or immunologic effects. There is growing evidence that diesel exhaust can exacerbate these effects, but the exposure-response data is presently lacking to derive an RfC. Again, this RfC is based on animal studies and is meant to estimate exposure that is unlikely to have deleterious effects on humans based on those studies alone.

The Diesel HAD also briefly summarizes health effects associated with ambient PM and the EPA's annual NAAQS for $PM_{2.5}$ of 15 ug/m^3. There is a much more extensive body of human data showing a wide spectrum of adverse health effects associated with exposure to ambient PM, of which diesel exhaust is an important component due to its large contribution to ambient concentrations. The RfC is not meant to say that 5 ug/m^3 provides adequate public health protection for ambient $PM_{2.5}$. There may be benefits to reducing diesel PM below 5 ug/m^3 since diesel PM is a major contributor to ambient $PM_{2.5}$. Recent epidemiologic studies of ambient PM2.5 do not indicate a threshold of effects at low concentrations.[37]

Also, as mentioned earlier in the health effects discussion for $PM_{2.5}$, there are a number of other health effects associated with PM in general, and motor vehicle exhaust including diesels in particular, that provide additional evidence for the need for significant emission reductions from nonroad diesel sources. For example, the Diesel HAD notes that acute or short-term exposure to diesel exhaust can cause acute irritation (*e.g.*, eye, throat, bronchial), neurophysiological symptoms (*e.g.*, lightheadedness, nausea), and respiratory symptoms (*e.g.*, cough, phlegm). There is also evidence for an immunologic effect such as the exacerbation of allergenic responses to know allergens and asthma-like symptoms. All of these health effects plus the designation of diesel exhaust as a likely human carcinogen provide ample health justification for control.

iii. Ambient Levels and Exposure to Diesel Exhaust PM

Because diesel PM is part of overall ambient PM and cannot be easily distinguished from overall PM, we do not have direct measurements of diesel PM in the ambient air. Ambient diesel PM concentrations are estimated instead using one of three approaches: (1) Ambient air quality modeling based on diesel PM emission inventories; (2) using elemental carbon concentrations in monitored data as surrogates; or (3) using the chemical mass balance (CMB) model in conjunction with ambient PM measurements. (Also, in addition to CMB, UNMIX/PMF have also been used). Estimates using these three approaches are described below. In addition, estimates developed using the first two approaches above are subjected to a statistical comparison to evaluate overall reasonableness of estimated concentrations. It is important to note that, while there are inconsistencies in some of these studies on the relative importance of gasoline and diesel PM, the studies which are discussed in the Diesel HAD all show that diesel PM is a significant contributor to overall ambient PM. Some of the studies differentiate nonroad from on-road diesel PM.

(1) Air Quality Modeling

In addition to the general ambient PM modeling conducted for this proposal, diesel PM concentrations specifically were recently estimated for 1996 as part of NATA. In this assessment, the PM inventory developed for the recent regulation promulgating 2007 heavy duty vehicle standards was used. Note that the nonroad inventory used in this modeling was based on an older version of the draft NONROAD Model which showed higher diesel PM than the current version. Ambient impacts of mobile source emissions were predicted using the Assessment System for Population Exposure Nationwide (ASPEN) dispersion model. Overall mean annual national levels for both on-road and nonroad diesels of 2.06 ug/m^3 diesel PM were calculated with a mean of 2.41 in urban counties and 0.74 in rural counties. These are ambient levels such as would be seen at monitors rather than the exposure levels discussed earlier. Over half of the diesel PM comes from nonroad diesels.

Diesel PM concentrations were also recently modeled across a representative urban area, Houston, for 1996, using the Industrial Source Complex Short Term (ISCST3) model. This modeling is designed to more specifically account for local traffic patterns including diesel truck traffic along specific roadways. The modeling in Houston suggests strong spatial gradients for Diesel PM and indicates that ''hotspot'' concentrations can be very high, up to 8 ug/m^3 at receptor versus a 3 ug/m^3 average in Houston. Such concentrations are above the RfC for diesel exhaust and indicate a potential for adverse health effects from chronic exposure to diesel PM. These results also suggest that PM from diesel vehicles makes a major contribution to total ambient PM concentrations. Such ''hot spot'' concentrations along certain roadways suggest the presence of both high localized exposures plus higher estimated average annual exposure levels for urban centers than what has been estimated in assessments such as NATA, which are designed to focus on regional and national scale averages. There are similar ''hot spot'' concentrations in the immediate vicinity of use of nonroad equipment such as in urban construction sites.

(2) Elemental Carbon Measurements

As mentioned before, the carbonaceous component is significant in ambient PM. The carbonaceous component consists of organic carbon and elemental carbon. Monitoring data on elemental carbon concentrations can be used as a surrogate to determine ambient diesel PM concentrations. Elemental carbon is a major component of diesel exhaust, contributing to approximately 60 to 80 percent of diesel particulate mass, depending on engine technology, fuel type, duty cycle, lube oil consumption, and state of engine maintenance. In most areas, diesel engine emissions are major contributors to elemental carbon in the ambient air, with other potential sources including gasoline exhaust, combustion of coal, oil, or wood (including forest fires), charbroiling, cigarette smoke, and road dust. Because of the large portion of elemental carbon in diesel particulate matter, and the fact that diesel exhaust is one of the major contributors to elemental carbon in most areas, ambient diesel PM concentrations can be bounded using elemental carbon measurements.

The measured mass of elemental carbon at a given site varies depending on the measurement technique used. Moreover, to estimate diesel PM concentration based on elemental

[37] EPA–SAB-Council-ADV–99–012, 1999. The Clean Air Act Amendments Section 812 Prospective Study of Costs and Benefits (1999): Advisory by the Health and Ecological Effects Subcommittee on Initial Assessments of Health and Ecological Effects, Part 1. July 28, 1999.

carbon level, one must first estimate the percentage of PM attributable to diesel engines and the percentage of elemental carbon in diesel PM. Thus, there are significant uncertainties in estimating diesel PM concentrations using an elemental carbon surrogate. Depending on the measurement technique used, and assumptions made, average nationwide concentrations for current years of diesel PM estimated from elemental carbon data range from about 1.2 to 2.2 ug/m^3. EPA has compared these estimates based on elemental carbon measurements to modeled concentrations in NATA and concluded that the two sets of data agree reasonably well. This performance compares favorably with the model to monitor results for other pollutants assessed in NATA, with the exception of benzene, for which the performance of the NATA modeling was better. These comparisons are discussed in greater detail in the draft RIA.

(3) Chemical Mass Balance

The third approach for estimating ambient diesel PM concentrations uses the CMB model for source apportionment in conjunction with ambient PM measurements and chemical source ''fingerprints'' to estimate ambient diesel PM concentrations. The CMB model uses a statistical fitting technique to determine how much mass from each source would be required to reproduce the chemical fingerprint of each speciated ambient monitor. This source apportionment technique presently does not distinguish between on-road and nonroad but, instead, gives diesel PM as a whole. This source apportionment technique can distinguish between diesel and gasoline PM. Caution in interpreting CMB results is warranted, as the use of fitting species that are not specific to the sources modeled can lead to misestimation of source contributions. Ambient concentrations using this approach are generally about 1 ug/m^3 annual average. UNMIX/PMF models show similar results. Results from various studies are discussed in the draft RIA.

iv. Diesel Exhaust PM Exposures

Exposure of people to diesel exhaust depends on their various activities, the time spent in those activities, the locations where these activities occur, and the levels of diesel exhaust pollutants (such as particulate) in those locations. The major difference between ambient levels of diesel particulate and exposure levels for diesel particulate is that exposure accounts for a person moving from location to location, proximity to the emission source, and whether the exposure occurs in an enclosed environment.

(1) Occupational Exposures

Diesel particulate exposures have been measured for a number of occupational groups over various years but generally for more recent years (1980s and later) rather than earlier years. Occupational exposures had a wide range varying from 2 to 1,280 ug/m^3 for a variety of occupational groups including miners, railroad workers, firefighters, air port crew, public transit workers, truck mechanics, utility linemen, utility winch truck operators, fork lift operators, construction workers, truck dock workers, short-haul truck drivers, and long-haul truck drivers. These individual studies are discussed in the Diesel HAD. As discussed in the Diesel HAD, the National Institute of Occupational Safety and Health (NIOSH) has estimated a total of 1,400,000 workers are occupationally exposed to diesel exhaust from on-road and nonroad equipment.

Many measured or estimated occupational exposures are for on-road diesel engines although some (especially the higher ones) are for occupational groups (*e.g.*, fork lift operators, construction workers, or mine workers) who would be exposed to nonroad diesel exhaust. Sometimes, as is the case for the nonroad engines, there are only estimates of exposure based on the length of employment or similar factors rather than a ug/m^3 level. Estimates for exposures to diesel PM for diesel fork lift operators have been made that range from 7 to 403 ug/m^3 as reported in the Diesel HAD. In addition, the Northeast States for Coordinated Air Use Management (NESCAUM) is presently measuring occupational exposures to particulate and elemental carbon near the operation of various diesel non-road equipment. Exposure groups include agricultural farm operators, grounds maintenance personnel (lawn and garden equipment), heavy equipment operators conducting multiple job tasks at a construction site, and a saw mill crew at a lumber yard. Samples will be obtained in the breathing zone of workers. Some initial results are expected in late 2003.

(2) General Ambient Exposures

Currently, personal exposure monitors for PM cannot differentiate diesel from other PM. Thus, we use modeling to estimate exposures. Specifically, exposures for the general population are estimated by first conducting dispersion modeling of both on-road and non-road diesel emissions, described above, and then by conducting exposure modeling. The most comprehensive modeling for cumulative exposures to diesel PM is the NATA. This assessment calculates exposures of the national population as a whole to a variety of air toxics, including diesel PM. As discussed previously, the ambient levels are calculated using the ASPEN dispersion model. The preponderance of modeled diesel PM concentrations are within a factor of 2 of diesel PM concentrations estimated from elemental carbon measurements.[38] This comparison adds credence to the modeled ASPEN results and associated exposure assessment.

The modeled ambient concentrations are used as inputs into the Hazardous Air Pollution Exposure Model (HAPEM4) to calculate exposure levels. Average exposures calculated nationwide are 1.44 ug/m^3 with levels of 1.64 ug/m^3 for urban counties and 0.55 ug/m^3 for rural counties. Again, nonroad diesels account for over half of this modeled exposure.

(3) Ambient Exposures—Microenvironments

One common microenvironment for diesel exposure is beside freeways. Although freeway locations are associated mostly with on-road rather than nonroad diesels, there are many similarities between on-road and nonroad diesel emissions as discussed in the Diesel HAD. The California Air Resources Board (CARB) measured elemental carbon near the Long Beach Freeway in 1993. Levels measured ranged from 0.4 to 4.0 ug/m^3 (with one value as high as 7.5 ug/m^3) above background levels. Microenvironments associated with nonroad engines would include construction zones. PM and elemental carbon samples are being collected by NESCAUM in the immediate area of the nonroad engine operations (such as at the edge or fence line of the construction zone). Besides PM and elemental carbon levels, various toxics such as benzene, 1,3-butadiene, formaldehyde, and acetaldehyde will be sampled. Some initial results should be available in late 2003 and will be especially useful since they focus on those microenvironments affected by nonroad diesels.

Also, EPA is funding research in Fresno to measure indoor and outdoor PM component concentrations in the homes of over 100 asthmatic children. Some of these homes are located near

[38] U.S. EPA (2002). Diesel PM model-to-measurement comparison. Prepared by ICF Consulting for EPA, Office of Transportation and Air Quality. Report No. EPA420–D–02–004.

agricultural, construction, and utility nonroad equipment operations. This work will measure infiltration of elemental carbon and other PM components to indoor environments. The project also evaluates lung function changes in the asthmatic children during fluctuations in exposure concentrations and compositions. This information may allow an evaluation of adverse health effects associated with exposures to elemental carbon and other PM components from on-road and nonroad sources. Some initial results may be available in late 2003.

b. Gaseous Air Toxics

Nonroad diesel engine emissions contain several substances known or suspected as human or animal carcinogens, or that have noncancer health effects. These other compounds include benzene,1,3-butadiene, formaldehyde, acetaldehyde, acrolein, dioxin, and polycyclic organic matter (POM). For some of these pollutants, nonroad diesel engine emissions are believed to account for a significant proportion of total nation-wide emissions. All of these compounds were identified as national or regional ''risk'' drivers in the 1996 NATA. That is, these compounds pose a significant portion of the total inhalation cancer risk to a significant portion of the population. Mobile sources contribute significantly to total emissions of these air toxics. As discussed later in this section, this proposed rulemaking will result in significant reductions of these emissions.

Benzene: Nonroad diesel engines accounted for about 3 percent of ambient benzene emissions in 1996. Of ambient benzene levels due to mobile sources, 5 percent in urban and 3 percent in rural areas came from nonroad diesel.

The EPA's IRIS database lists benzene as a known human carcinogen (causing leukemia at high, prolonged air exposures) by all routes of exposure, and exposure is associated with additional health effects including genetic changes in humans and animals and increased proliferation of bone marrow cells in mice.[39] [40] [41] [42] EPA states in its IRIS database that the data indicate a causal relationship between benzene exposure and acute lymphocytic leukemia and suggest a relationship between benzene exposure and chronic non-lymphocytic leukemia and chronic lymphocytic leukemia. Respiration is the major source of human exposure and at least half of this exposure is attributable to gasoline vapors and automotive emissions. A number of adverse noncancer health effects including blood disorders, such as preleukemia and aplastic anemia, have also been associated with low-dose, long-term exposure to benzene.[43] [44]

1,3-Butadiene: Nonroad diesel engines accounted for about 1.5 percent of ambient butadiene emissions in 1996. Of ambient butadiene levels due to mobile sources, 4 percent in urban and 2 percent in rural areas came from nonroad diesel.

EPA earlier identified 1,3-butadiene as a probable human carcinogen in its IRIS database and recently redesignated it as a known human carcinogen (but with a lower carcinogenic potency than previously used).[45] The specific mechanisms of 1,3-butadiene-induced carcinogenesis are unknown, however, it is virtually certain that the carcinogenic effects are mediated by genotoxic metabolites of 1,3-butadiene. Animal data suggest that females may be more sensitive than males for cancer effects; nevertheless, there are insufficient data from which to draw any conclusions on potentially sensitive subpopulations. 1,3-Butadiene also causes a variety of reproductive and developmental effects in mice; no human data on these effects are available. The most sensitive effect was ovarian atrophy observed in a lifetime bioassay of female mice.[46]

Formaldehyde: Nonroad diesel engines accounted for about 22 percent of ambient formaldehyde emissions in 1996. Of ambient formaldehyde levels due to mobile sources, 37 percent in urban and 27 percent in rural areas came form nonroad diesel. These figures are for tailpipe emissions of formaldehyde. Formaldehyde in the ambient air comes not only from tailpipe (of direct) emissions but is also formed from photochemical reactions of hydrocarbons.

EPA has classified formaldehyde as a probable human carcinogen based on evidence in humans and in rats, mice, hamsters, and monkeys.[47] Epidemiological studies in occupationally exposed workers suggest that long-term inhalation of formaldehyde may be associated with tumors of the nasopharyngeal cavity (generally the area at the back of the mouth near the nose), nasal cavity, and sinus.[48] Formaldehyde exposure also causes a range of noncancer health effects, including irritation of the eyes (tearing of the eyes and increased blinking) and mucous membranes. Sensitive individuals may experience these adverse effects at lower concentrations than the general population and in persons with bronchial asthma, the upper respiratory irritation caused by formaldehyde can precipitate an acute asthmatic attack. The agency is currently conducting a reassessment of risk from inhalation exposure to formaldehyde.

Acetaldehyde: Nonroad diesel engines accounted for about 34 percent of acetaldehyde emissions in 1996. Of ambient acetaldehyde levels due to mobile sources, 24 percent in urban and 17 percent in rural areas came form nonroad diesel. Also, acetaldehyde can be formed photochemically in the atmosphere. Counting both direct emissions and photochemically formed acetaldehyde, mobile sources were responsible for the major portion of acetaldehyde in the ambient air according to the National-Scale Air Toxics Assessment for 1996.

Acetaldehyde is classified in EPA's IRIS database as a probable human carcinogen and is considered moderately toxic by the inhalation, oral, and intravenous routes.[49] The primary acute effect of exposure to acetaldehyde vapors is irritation of the eyes, skin, and

[39] U.S. EPA (2000). Integrated Risk Information System File for Benzene. This material is available electronically at *http://www.epa.gov/iris/subst/0276.htm.*

[40] International Agency for Research on Cancer, IARC monographs on the evaluation of carcinogenic risk of chemicals to humans, Volume 29, Some industrial chemicals and dyestuffs, International Agency for Research on Cancer, World Health Organization, Lyon, France, p. 345–389, 1982.

[41] Irons, R.D., W.S. Stillman, D.B. Colagiovanni, and V.A. Henry, Synergistic action of the benzene metabolite hydroquinone on myelopoietic stimulating activity of granulocyte/macrophage colony-stimulating factor *in vitro,* Proc. Natl. Acad. Sci. 89:3691–3695, 1992.

[42] U.S. EPA (1998). Carcinogenic Effects of Benzene: An Update, National Center for Environmental Assessment, Washington, DC. 1998.

[43] Aksoy, M. (1989). Hematotoxicity and carcinogenicity of benzene. Environ. Health Perspect. 82: 193–197.

[44] Goldstein, B.D. (1988). Benzene toxicity. Occupational medicine. State of the Art Reviews. 3: 541–554.

[45] U.S. EPA (2002). Health Assessment of 1,3-Butadiene. Office of Research and Development, National Center for Environmental Assessment, Washington Office, Washington, DC. Report No. EPA/600/P–98/001F.

[46] Bevan, C; Stadler, JC; Elliot, GS; *et al.* (1996) Subchronic toxicity of 4-vinylcyclohexene in rats and mice by inhalation. Fundam. Appl. Toxicol. 32:1–10.

[47] U.S. EPA (1987). Assessment of Health Risks to Garment Workers and Certain Home Residents from Exposure to Formaldehyde, Office of Pesticides and Toxic Substances, April 1987.

[48] Blair, A., P.A. Stewart, R.N. Hoover, *et al.* (1986). Mortality among industrial workers exposed to formaldehyde. J. Natl. Cancer Inst. 76(6): 1071–1084.

[49] U.S. EPA (1988). Integrated Risk Information System File of Acetaldehyde. This material is available electronically at *http://www.epa.gov/iris/subst/0290.htm.*

respiratory tract. At high concentrations, irritation and pulmonary effects can occur, which could facilitate the uptake of other contaminants. Some asthmatics have been shown to be a sensitive subpopulation to decrements in FEV1 upon acetaldehyde inhalation.[50] The agency is currently conducting a reassessment of risk from inhalation exposure to acetaldehyde.

Acrolein: Nonroad diesel engines accounted for about 17.5 percent of acrolein emissions in 1996. Of ambient acrolein levels due to mobile sources, 28 percent in urban and 18 percent in rural areas came form nonroad diesel.

Acrolein is extremely toxic to humans when inhaled, with acute exposure resulting in upper respiratory tract irritation and congestion. The Agency has developed a reference concentration for inhalation (RfC) of acrolein of 0.02 micrograms/m^3.[51]

Although no information is available on its carcinogenic effects in humans, based on laboratory animal data, EPA considers acrolein a possible human carcinogen.

Polycyclic Organic Matter (POM): POM is generally defined as a large class of chemicals consisting of organic compounds having multiple benzene rings and a boiling point greater than 100 degrees C. Polycyclic aromatic hydrocarbons (PAHs) are a chemical class that is a subset of POM. POM are naturally occurring substances that are byproducts of the incomplete combustion of fossil fuels and plant and animal biomass (*e.g.*, forest fires). They occur as byproducts from steel and coke productions and waste incineration. They also are a component of diesel particulate emissions. Many of the compounds included in the class of compounds known as POM are classified by EPA as probable human carcinogens based on animal data. In particular, EPA frequently obtains data on 7 of the POM compounds, which we analyzed separately as a class in the 1996 NATA. Nonroad diesel engines account for less than 1 percent of these 7 POM compounds with total mobile sources responsible for only 4 percent of the total; most of the 7 POMs come from area sources. For total POM compounds, mobile sources as a whole are responsible for only 1 percent. The mobile source emission numbers used to derive these inventories are based on only particulate phase POM and do not include the semi-volatile phase POM levels. Were those additional POMs included (which is now being done), these inventory numbers would be substantially higher.

Even though mobile sources are responsible for only a small portion of total POM emissions, the particulate reductions from today's action will reduce these emissions.

Dioxins: Recent studies have confirmed that dioxins are formed by and emitted from diesels (both heavy-duty diesel trucks and non-road diesels although in very small amounts) and are estimated to account for about 1 percent of total dioxin emissions in 1995. Recently EPA issued a draft assessment designating one dioxin compound, 2,3,7,8-tetrachlorodibenzo-p-dioxin as a human carcinogen and the complex mixtures of dioxin-like compounds as likely to be carcinogenic to humans using the draft 1996 carcinogen risk assessment guidelines. EPA is working on its final assessment for dioxin.[52] An interagency review group is evaluating EPA's designation of dioxin as a likely human carcinogen. Reductions from today's nonroad proposal will have minimal impact on overall dioxin emissions.

3. Ozone

a. What Are the Health Effects of Ozone Pollution?

Ground-level ozone pollution (sometimes called "smog") is formed by the reaction of volatile organic compounds (VOC) and nitrogen oxides (NO_X) in the atmosphere in the presence of heat and sunlight. These two pollutants, often referred to as ozone precursors, are emitted by many types of pollution sources, including on-road and off-road motor vehicles and engines, power plants and industrial facilities, and smaller "area" sources.

Ozone can irritate the respiratory system, causing coughing, throat irritation, and/or uncomfortable sensation in the chest.[53] [54] Ozone can reduce lung function and make it more difficult to breathe deeply, and breathing may become more rapid and shallow than normal, thereby limiting a person's normal activity. Ozone also can aggravate asthma, leading to more asthma attacks that require a doctor's attention and/or the use of additional medication. In addition, ozone can inflame and damage the lining of the lungs, which may lead to permanent changes in lung tissue, irreversible reductions in lung function, and a lower quality of life if the inflammation occurs repeatedly over a long time period (months, years, a lifetime). People who are of particular concern with respect to ozone exposures include children and adults who are active outdoors. Those people particularly susceptible to ozone effects are people with respiratory disease, such as asthma, and people with unusual sensitivity to ozone, and children. Beyond its human health effects, ozone has been shown to injure plants, which has the effect of reducing crop yields and reducing productivity in forest ecosystems.[55] [56]

The 8-hour ozone standard, established by EPA in 1997, is based on well-documented science demonstrating that more people are experiencing adverse health effects at lower levels of exertion, over longer periods, and at lower ozone concentrations than addressed by the one-hour ozone standard. (*See, e.g.*, 62 FR 38861–62, July 18, 1997). The 8-hour standard addresses ozone exposures of concern for the general population and populations most at risk, including children active outdoors, outdoor workers, and individuals with pre-existing respiratory disease, such as asthma.

There has been new research that suggests additional serious health effects beyond those that had been known when the 8-hour ozone health standard was set. Since 1997, over 1,700 new health and welfare studies relating to ozone have been published in peer-reviewed journals.[57] Many of these studies have investigated the impact of ozone exposure on such health effects as changes in lung structure and biochemistry, inflammation of the

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[50] Myou, S.; Fujimura, M.; Nishi K.; Ohka, T.; and Matsuda, T. (1993) Aerosolized acetaldehyde induces histamine-mediated bronchoconstriction in asthmatics. Am Rev Respir Dis 148(4 Pt 1): 940–3.

[51] U.S. EPA (1993). Environmental Protection Agency, Integrated Risk Information System (IRIS), National Center for Environmental Assessment, Cincinnati, OH.

[52] U.S. EPA (June 2000) Exposure and Human Health Reassessment of 2,3,7,8-Tetrachlorodibenzo-p-Dioxin (TCDD) and Related Compounds, External Review Draft, EPA/600/P–00/001Ag. This material is available electronically at *http://www.epa.gov/ncea/dioxin.htm.*

[53] U.S. EPA (1996). Air Quality Criteria for Ozone and Related Photochemical Oxidants, EPA/600/P–93/004aF. Docket No. A–99–06. Document Nos. II–A–15 to 17.

[54] U.S. EPA. (1996). Review of National Ambient Air Quality Standards for Ozone, Assessment of Scientific and Technical Information, OAQPS Staff Paper, EPA–452/R–96–007. Docket No. A–99–06. Document No. II–A–22.

[55] U.S. EPA (1996). Air Quality Criteria for Ozone and Related Photochemical Oxidants, EPA/600/P–93/004aF. Docket No. A–99–06. Document Nos. II–A–15 to 17.

[56] U.S. EPA. (1996). Review of National Ambient Air Quality Standards for Ozone, Assessment of Scientific and Technical Information, OAQPS Staff Paper, EPA–452/R–96–007. Docket No. A–99–06. Document No. II–A–22.

[57] New Ozone Health and Environmental Effects References, Published Since Completion of the Previous Ozone AQCD, National Center for Environmental Assessment, Office of Research and Development, U.S. Environmental Protection Agency, Research Triangle Park, NC 27711 (7/2002) Docket No. A–2001–11. Document No. IV–A–19.

lungs, exacerbation and causation of asthma, respiratory illness-related school absence, hospital and emergency room visits for asthma and other respiratory causes, and premature mortality. EPA is currently in the process of evaluating these and other studies as part of the ongoing review of the air quality criteria and NAAQS for ozone. A revised Air Quality Criteria Document for Ozone and Other Photochemical Oxidants will be prepared in consultation with EPA's Clean Air Science Advisory Committee (CASAC). Key new health information falls into four general areas: development of new-onset asthma, hospital admissions for young children, school absence rate, and premature mortality.

Aggravation of existing asthma resulting from short-term ambient ozone exposure was reported prior to the 1997 decision and has been observed in studies published subsequently.[58] [59] In particular, a relationship between long-term ambient ozone concentrations and the incidence of new-onset asthma in adult males (but not in females) was reported by McDonnell *et al.* (1999).[60] Subsequently, an additional study suggests that incidence of new diagnoses of asthma in children is associated with heavy exercise in communities with high concentrations (*i.e.*, mean 8-hour concentration of 59.6 ppb) of ozone.[61] This relationship was documented in children who played 3 or more sports and thus had higher exposures and was not documented in those children who played one or two sports. The larger effect of high activity sports than low activity sports and an independent effect of time spent outdoors also in the higher ozone communities strengthened the inference that exposure to ozone may modify the effect of sports on the development of asthma in some children.

Previous studies have shown relationships between ozone and hospital admissions in the general population. A study in Toronto reported a significant relationship between 1-hour maximum ozone concentrations and respiratory hospital admissions in children under the age of two.[62] Given the relative vulnerability of children in this age category, we are particularly concerned about the findings.

Increased respiratory disease that are serious enough to cause school absences have been associated with 1-hour daily maximum and 8-hour average ozone concentrations in studies conducted in Nevada[63] in kindergarten to 6th grade and in Southern California in grades 4 through 6.[64] These studies suggest that higher ambient ozone levels may result in increased school absenteeism.

The air pollutant most clearly associated with premature mortality is PM, with dozens of studies reporting such an association. However, repeated ozone exposure is a possible contributing factor for premature mortality, causing an inflammatory response in the lungs which may predispose elderly and other sensitive individuals to become more susceptible to other stressors, such as PM.[65] [66] [67] Although the findings have been mixed, the findings of three recent analyses suggest that ozone exposure is associated with increased mortality. Although the National Morbidity, Mortality, and Air Pollution Study (NMMAPS) did not report an effect of ozone on total mortality across the full year, the investigators who conducted the NMMAPS study did observe an effect after limiting the analysis to summer when ozone levels are highest.[68] [69] Similarly, other studies have shown associations between ozone and mortality.[70] [71] Specifically, Toulomi *et al.* (1997) found that 1-hour maximum ozone levels were associated with daily numbers of deaths in 4 cities (London, Athens, Barcelona, and Paris), and a quantitatively similar effect was found in a group of four additional cities (Amsterdam, Basel, Geneva, and Zurich).

In all, the new studies that have become available since the 8-hour ozone standard was adopted in 1997 continue to demonstrate the harmful effects of ozone on public health, and the need to attain and maintain the NAAQS.

b. Current and projected 8-hour ozone levels

As shown earlier (Figure II–1), unhealthy ozone concentrations exceeding the level of the 8-hour standard (*i.e.*, not requisite to protect the public health with an adequate margin of safety) occur over wide geographic areas, including most of the nation's major population centers. These monitored areas include much of the eastern half of the U.S. and large areas of California.

Based upon data from 1999–2001, there are 291 counties where 111 million people live that are measuring values that violate the 8-hour ozone NAAQS.[72] An additional 37 million people live in 155 counties that have air quality measurements within 10 percent of the level of the standard. These areas, though currently not violating the standard, will also benefit from the additional emission reductions from this rule.

From our air quality modeling for this proposal, we anticipate that without emission reductions beyond those

[58] Thurston, G.D., M.L. Lippman, M.B. Scott, and J.M. Fine. 1997. Summertime Haze Air Pollution and Children with Asthma. American Journal of Respiratory Critical Care Medicine, 155: 654–660.

[59] Ostro, B, M. Lipsett, J. Mann, H. Braxton-Owens, and M. White (2001) Air pollution and exacerbation of asthma in African-American children in Los Angeles. Epidemiology 12(2): 200–208.

[60] McDonnell, W.F., D.E. Abbey, N. Nishino and M.D. Lebowitz. 1999. "Long-term ambient ozone concentration and the incidence of asthma in nonsmoking adults: the ahsmog study." Environmental Research. 80(2 Pt 1): 110–121.

[61] McConnell, R.; Berhane, K.; Gilliland, F.; London, S.J.; Islam, T.; Gauderman, W.J.; Avol, E.; Margolis, H.G.; Peters, J.M. (2002) Asthma in exercising children exposed to ozone: a cohort study. Lancet 359: 386–391.

[62] Burnett, R.T.; Smith_Doiron, M.; Stieb, D.; Raizenne, M.E.; Brook, J.R.; Dales, R.E.; Leech, J.A.; Cakmak, S.; Krewski, D. (2001) Association between ozone and hospitalization for acute respiratory diseases in children less than 2 years of age. Am. J. Epidemiol. 153: 444–452.

[63] Chen, L.; Jennison, B.L.; Yang, W.; Omaye, S.T. (2000) Elementary school absenteeism and air pollution. Inhalation Toxicol. 12: 997–1016.

[64] Gilliland, FD, K Berhane, EB Rappaport, DC Thomas, E Avol, WJ Gauderman, SJ London, HG Margolis, R McConnell, KT Islam, JM Peters (2001) The effects of ambient air pollution on school absenteeism due to respiratory illnesses Epidemiology 12:43–54.

[65] Samet JM, Zeger SL, Dominici F, Curriero F, Coursac I, Dockery DW, Schwartz J, Zanobetti A. 2000. The National Morbidity, Mortality and Air Pollution Study: Part II: Morbidity, Mortality and Air Pollution in the United States. Research Report No. 94, Part II. Health Effects Institute, Cambridge MA, June 2000. (Docket Number A–2000–01, Document Nos. IV–A–208 and 209).

[66] Devlin, R.B.; Folinsbee, L.J.; Biscardi, F.; Hatch, G.; Becker, S.; Madden, M.C.; Robbins, M.; Koren, H. S. (1997) Inflammation and cell damage induced by repeated exposure of humans to ozone. Inhalation Toxicol. 9: 211–235.

[67] Koren HS, Devlin RB, Graham DE, Mann R, McGee MP, Horstman DH, Kozumbo WJ, Becker S, House DE, McDonnell SF, Bromberg, PA. 1989. Ozone-induced inflammation in the lower airways of human subjects. Am. Rev. Respir. Dies. 139: 407–415.

[68] Samet JM, Zeger SL, Dominici F, Curriero F, Coursac I, Dockery DW, Schwartz J, Zanobetti A. 2000. The National Morbidity, Mortality and Air Pollution Study: Part II: Morbidity, Mortality and Air Pollution in the United States. Research Report No. 94, Part II. Health Effects Institute, Cambridge MA, June 2000. (Docket Number A–2000–01, Documents No. IV–A–208 and 209).

[69] Samet JM, Zeger SL, Dominici F, Curriero F, Coursac I, Zeger, S. Fine Particulate Air Pollution and Mortality in 20 U.S. Cities, 1987—1994. The New England Journal of Medicine. Vol. 343, No. 24, December 14, 2000. P. 1742–1749.

[70] Thurston, G.D.; Ito, K. (2001) Epidemiological studies of acute ozone exposures and mortality. J. Exposure Anal. Environ. Epidemiol. 11: 286–294.

[71] Touloumi, G.; Katsouyanni, K.; Zmirou, D.; Schwartz, J.; Spix, C.; Ponce de Leon, A.; Tobias, A.; Quennel, P.; Rabczenko, D.; Bacharova, L.; Bisanti, L.; Vonk, J.M.; Ponka, A. (1997) Short-term effects of ambient oxidant exposure on mortality: a combined analysis within the APHEA project. Am. J. Epidemiol. 146: 177–185.

[72] Additional counties may have levels above the NAAQS but do not currently have monitors.

already required under promulgated regulation and approved SIPs, ozone nonattainment will likely persist into the future. With reductions from programs already in place, the number of counties violating the ozone 8-hour standard is expected to decrease in 2020 to 30 counties where 43 million people are projected to live. Thereafter, exposure to unhealthy levels of ozone is expected to begin to increase again. In 2030 the number of counties violating the ozone 8-hour NAAQS is projected to increase to 32 counties where 47 million people are projected to live. In addition, in 2030, 82 counties where 44 million people are projected to live will be within 10 percent of violating the ozone 8-hour NAAQS.

EPA is still developing the implementation process for bringing the nation's air into attainment with the ozone 8-hour NAAQS. EPA's current plans call for designating ozone 8-hour nonattainment areas in April 2004. EPA is planning to propose that States submit SIPs that address how areas will attain the 8-hour ozone standard within three years after nonattainment designation regardless of their classification. EPA is also planning to propose that certain SIP components, such as those related to reasonably available control technology (RACT) and reasonable further progress (RFP) be submitted within 2 years after designation. We therefore anticipate that States will submit their attainment demonstration SIPs by April 2007. Section 172(a)(2) of the Clean Air Act requires that SIP revisions for areas that may be covered only under subpart 1 of part D, title I of the Act demonstrate that the nonattainment areas will attain the ozone 8-hour standard as expeditiously as practicable but no later than five years from the date that the area was designated nonattainment. However, based on the severity of the air quality problem and the availability and feasibility of control measures, the Administrator may extend the attainment date ''for a period of no greater than 10 years from the date of designation as nonattainment.'' Based on these provisions, we expect that most or all areas covered under subpart 1 will attain the ozone standard in the 2007 to 2014 time frame. For areas covered under subpart 2, the maximum attainment dates provided under the Act range from 3 to 20 years after designation, depending on an area's classification. Thus, we anticipate that areas covered by subpart 2 will attain in the 2007 to 2014 time period.

Since the emission reductions expected from this proposal would begin during the same time period, the projected reductions in nonroad emissions would be extremely important to States in their effort to meet the new NAAQS. It is our expectation that States will be relying on such nonroad reductions in order to help them attain and maintain the 8-hour NAAQS. Furthermore, since the nonroad emission reductions will continue to grow in the years beyond 2014, they will also be important for maintenance of the NAAQS for areas with attainment dates of 2014 and earlier.

Using air quality modeling of the impacts of emission reductions, we have made estimates of the change in future ozone levels that would result from the proposed rule.[73] That modeling shows that this rule would produce nationwide air quality improvements in ozone levels. On a population-weighted basis, the average change in future year design values would be a decrease of 1.6 ppb in 2020, and 2.6 ppb in 2030. Within areas predicted to violate the NAAQS in the projected base case, the average decrease would be somewhat higher: 1.9 ppb in 2020 and 3.0 ppb in 2030.[74]

The model predictions of whether specific counties will violate the NAAQS or not is uncertain, especially for counties with design values falling very close to the standard. This makes us more confident in our prediction of average air quality changes than in our prediction of the exact numbers of counties projected as exceeding the NAAQS. Furthermore, actions by States to meet their SIP obligations will change the number of counties violating the NAAQS in the time frame we are modeling for this rule. If State actions resulted in an increase in the number of areas that are very close to, but still above, the NAAQS, then this rule might bring many of those counties down sufficiently to eliminate remaining violations. In addition, if State actions brought several counties we project to be very close to the standard in the future down sufficiently to eliminate violations, then the air quality improvements from this proposal might serve more to assist these areas in maintaining the standards than in changing their status. Bearing this in mind, our modeling indicates that, out of 32 counties predicted to violate the NAAQS, the proposal would reduce the number of violating counties by 2 in 2020 and by 4 in 2030, without consideration of new State or Federal programs.

C. Other Environmental Effects

The following section presents information on five categories of public welfare and environmental impacts related to nonroad heavy-duty vehicle emissions: visibility impairment, acid deposition, eutrophication of water bodies, plant damage from ozone, and water pollution resulting from deposition of toxic air pollutants with resulting effects on fish and wildlife.

1. Visibility

a. Visibility is Impaired by Fine PM and Precursor Emissions From Nonroad Engines Subject to this Proposed Rule

Visibility can be defined as the degree to which the atmosphere is transparent to visible light.[75] Fine particles with significant light-extinction efficiencies include organic matter, sulfates, nitrates, elemental carbon (soot), and soil. Size and chemical composition of particles strongly affects their ability to scatter or absorb light. Sulfates contribute to visibility impairment especially on the haziest days across the U.S., accounting in the rural Eastern U.S. for more than 60 percent of annual average light extinction on the best days and up to 86 percent of average light extinction on the haziest days. Nitrates and elemental carbon each typically contribute 1 to 6 percent of average light extinction on haziest days in rural Eastern U.S. locations.[76]

Visibility is important because it directly affects people's enjoyment of daily activities in all parts of the country. Individuals value good visibility for the well-being it provides them directly, both in where they live and work, and in places where they enjoy recreational opportunities.

[73] These results are ozone changes projected for the preliminary control option used for our modeling, as discussed in the Draft RIA in section 3.6. The proposal differs from the modeled control case based on updated information; however, we believe that the net results would approximate future emissions, although we anticipate the ozone changes might be slightly different.

[74] This is in spite of the fact that NO_X reductions can at certain times in some areas cause ozone levels to increase. Such ''disbenefits'' are predicted in our modeling, but these results make clear that the overall effect of the proposed rule is positive. *See* the draft RIA for more information.

[75] National Research Council, 1993. Protecting Visibility in National Parks and Wilderness Areas. National Academy of Sciences Committee on Haze in National Parks and Wilderness Areas. National Academy Press, Washington, DC. This document is available on the Internet at *http://www.nap.edu/books/0309048443/html/*. *See also* U.S. EPA Air Quality Criteria Document for Particulate Matter (1996) (available on the Internet at *http://cfpub.epa.gov/ncea/cfm/partmatt.cfm*) and Review of the National Ambient Air Quality Standards for Particulate Matter: Policy Assessment of Scientific and Technical Information. These documents can be found in Docket A–99–06, Documents No. II-A–23 and IV-A–130–32.

[76] U.S. EPA Trends Report 2001. This document is available on the Internet at *http://www.epa.gov/airtrends/*.

Visibility is also highly valued in significant natural areas such as national parks and wilderness areas, because of the special emphasis given to protecting these lands now and for future generations.

To quantify changes in visibility, we compute a light-extinction coefficient, which shows the total fraction of light that is decreased per unit distance. Visibility can be described in terms of visual range or light extinction and is reported using an indicator called deciview.[77] In addition to limiting the distance that one can see, the scattering and absorption of light caused by air pollution can also degrade the color, clarity, and contrast of scenes.

In addition, visibility impairment can be described by its impact over various periods of time, by its source, and the physical conditions in various regions of the country. Visibility impairment can be said to have a time dimension in that it might relate to short-term excursions or to longer periods (*e.g.*, worst 20 percent of days and annual average levels). Anthropogenic contributions account for about one-third of the average extinction coefficient in the rural West and more than 80 percent in the rural East. In the Eastern U.S., reduced visibility is mainly attributable to secondarily formed particles, particularly those less than a few micrometers in diameter, such as sulfates. While secondarily formed particles still account for a significant amount in the West, primary emissions contribute a larger percentage of the total particulate load than in the East. Because of significant differences related to visibility conditions in the Eastern and Western U.S., we present information about visibility by region.

Furthermore, it is important to note that even in those areas with relatively low concentrations of anthropogenic fine particles, such as the Colorado Plateau, small increases in anthropogenic fine particulate concentrations can lead to significant decreases in visual range. This is one of the reasons mandatory Federal Class I areas have been given special consideration under the Clean Air Act.[78]

b. Visibility Impairment Where People Live, Work and Recreate

The secondary PM NAAQS is designed to protect against adverse welfare effects which includes visibility impairment. In 1997, EPA established the secondary $PM_{2.5}$ NAAQS as equal to the primary (health-based) NAAQS of 15 ug/m3 (based on a 3-year average of the annual mean) and 65 ug/m^3 (based on a 3-year average of the 98th percentile of the 24-hour average value) (62 FR 38669, July 18, 1997). EPA concluded that $PM_{2.5}$ causes adverse effects on visibility in various locations, depending on PM concentrations and factors such as chemical composition and average relative humidity. In 1997, EPA demonstrated that visibility impairment is an important effect on public welfare and that unacceptable visibility impairment is experienced throughout the U.S., in multi-state regions, urban areas, and remote federal Class I areas. In many cities having annual mean $PM_{2.5}$ concentrations exceeding annual standard, improvements in annual average visibility resulting from the attainment of the annual $PM_{2.5}$ standard are expected to be perceptible to the general population. Based on annual mean monitored $PM_{2.5}$ data, many cities in the Northeast, Midwest, and Southeast as well as Los Angeles would be expected to experience perceptible improvements in visibility if the $PM_{2.5}$ annual standard were attained.

The updated monitoring data and air quality modeling, summarized above and presented in detail in the draft RIA, confirm that the visibility situation identified during the NAAQS review in 1997 is still likely to exist, and it will continue to persist when these proposed standards for nonroad diesel engines take effect. Thus, the determination in the NAAQS rulemaking about broad visibility impairment and related benefits from NAAQS compliance are still relevant.

Furthermore, in setting the $PM_{2.5}$ NAAQS, EPA acknowledged that levels of fine particles below the NAAQS may also contribute to unacceptable visibility impairment and regional haze problems in some areas, and section 169 of the Act provides additional authorities to remedy existing impairment and prevent future impairment in the 156 national parks, forests and wilderness areas labeled as mandatory Federal Class I areas (62 FR 38680–81, July 18, 1997).

In making determinations about the level of protection afforded by the secondary PM NAAQS, EPA considered how the section 169 regional haze program and the secondary NAAQS would function together.[79] Regional strategies are expected to improve visibility in many urban and non-Class I areas as well.

Fine particles may remain suspended for days or weeks and travel hundreds to thousands of kilometers, and thus fine particles emitted or created in one county may contribute to ambient concentrations in a neighboring region.[80]

The 1999–2001 $PM_{2.5}$ monitored values indicate that at least 74 million people live in areas where long-term ambient fine PM levels are at or above 15 $\mu g/m^3$.[81] Thus, at least these populations (plus those who travel to those areas) are experiencing significant visibility impairment, and emissions of PM and its precursors from nonroad diesel engines contribute to this impairment.[82]

Because of the importance of chemical composition and size to visibility, we used EPA's Regional Modeling System for Aerosols and Deposition (REMSAD)[83] model to project visibility conditions in 2020 and 2030 in terms of deciview, accounting for the chemical composition of the particles and transport of precursors. Our projections included anticipated emissions from the nonroad diesel engines subject to this proposed rule as well as all other sources.

Based on this modeling, we predict that in 2030, 85 million people (25

[77] Visual range can be defined as the maximum distance at which one can identify a black object against the horizon sky. It is typically described in miles or kilometers. Light extinction is the sum of light scattering and absorption by particles and gases in the atmosphere. It is typically expressed in terms of inverse megameters (Mm^{-1}), with larger values representing worse visibility. The deciview metric describes perceived visual changes in a linear fashion over its entire range, analogous to the decibel scale for sound. A deciview of 0 represents pristine conditions. Under many scenic conditions, a change of 1 deciview is considered perceptible by the average person.

[78] The Clean Air Act designates 156 national parks and wilderness areas as mandatory Federal Class I areas for visibility protection.

[79] U.S. EPA Review of the National Ambient Air Quality Standards for Particulate Matter: Policy Assessment of Scientific and Technical Information OAQPS Staff Paper. EPA–452/R–96–013. 1996. Docket Number A–99–06, Documents Nos. II-A–18, 19, 20, and 23. The particulate matter air quality criteria documents are also available at *http://www.epa.gov/ncea/partmatt.htm.*

[80] Review of the National Ambient Air Quality Standards for Particulate Matter: Policy Assessment for Scientific and Technical Information, OAQPS Staff Paper, EPA–452/R–96–013, July, 1996, at IV–7. This document is available from Docket A–99–06, Document II–A–23.

[81] U.S. EPA Air Quality Data Analysis 1999–2001. Technical Support Document for Regulatory Actions. March 2003.

[82] These populations would also be exposed to PM concentrations associated with the adverse health impacts discussed above.

[83] Additional information about the Regional Modeling System for Aerosols and Deposition (REMSAD) and our modeling protocols can be found in our Regulatory Impact Analysis: Heavy-Duty Engine and Vehicle Standards and Highway Diesel Fuel Sulfur Control Requirements, document EPA420-R–00–026, December 2000. Docket No. A–2000–01, Document No. A-II–13. This document is also available at *http://www.epa.gov/otaq/disel.htm#documents*.

percent of the future population) would be living in areas with visibility degradation where fine PM levels are above 15 μg/m3 annually.[84] Thus, at least a quarter of the population would experience visibility impairment in areas where they live, work and recreate.

As shown in Table I.C–1, accounting for the different visibility impact of the chemical constituents of the $PM_{2.5}$, in 2030 we expect visibility in the East to be about 20.5 deciviews (or visual range of 50 kilometers) on average, with poorer visibility in urban areas, compared to the average Eastern visibility conditions without man-made pollution of 9.5 deciviews (or visual range of 150 kilometers). Likewise, we expect visibility in the West to be about 8.8 deciviews (or visual range of 162 kilometers) on average in 2030, with poorer visibility in urban areas, compared to the average Western visibility conditions without man-made pollution of 5.3 deciviews (or visual range of 230 kilometers). Thus, the emissions from these nonroad diesel sources, especially SOx emissions that become sulfates in the atmosphere, contribute to future visibility impairment summarized in the table.

Control of nonroad land-based engines emissions, as shown in Table I.C–1, will improve visibility across the nation. Taken together with other programs, reductions from this proposal will help to improve visibility. Control of these emissions in and around areas with PM levels above the annual $PM_{2.5}$ NAAQS will likely improve visibility in other locations such as mandatory Federal Class I areas. Specifically, for a preliminary control option described in the draft RIA chapter 3.6 that is similar to our proposal, we expect on average for visibility to improve to about 0.33 deciviews in the East and 0.35 deciviews in the West. The improvement from our proposal is likely to be similar but slightly smaller than what was modeled due to the differences in emission reductions between the proposal and the modeled scenario.

TABLE I.C–1—SUMMARY OF MODELED 2030 NATIONAL VISIBILITY CONDITIONS

[Average annual deciviews]

Regions [a]	Predicted 2030 visibility baseline	Predicted 2030 visibility with rule controls [b]	Change in annual average deciviews
Eastern U.S.	20.54	20.21	0.33
Urban	21.94	21.61	0.33
Rural	19.98	19.65	0.33
Western U.S.	8.83	8.58	0.25
Urban	9.78	9.43	0.35
Rural	8.61	8.38	0.23

Notes:

[a] Eastern and Western Regions are separated by 100 degrees north longitude. Background visibility conditions differ by region. Natural background is 9.5 deciviews in the East and 5.3 in the West.

[b] The results illustrate the type of visibility improvements for the preliminary control option, as discussed in the Draft RIA. The proposal differs based on updated information; however, we believe that the net results would approximate future PM emissions, although we anticipate the visibility improvements would be slightly smaller.

c. Visibility Impairment in Mandatory Federal Class I Areas

The Clean Air Act establishes special goals for improving visibility in many national parks, wilderness areas, and international parks. In the 1990 Clean Air Act amendments, Congress provided additional emphasis on regional haze issues (*see* CAA section 169B). In 1999, EPA finalized a rule that calls for States to establish goals and emission reduction strategies for improving visibility in all 156 mandatory Federal Class I areas. In that rule, EPA established a ''natural visibility'' goal, and also encouraged the States to work together in developing and implementing their air quality plans. The regional haze program is focused on long-term emissions decreases from the entire regional emissions inventory comprised of major and minor stationary sources, area sources and mobile sources. The regional haze program is designed to improve visibility and air quality in our most treasured natural areas from these broad sources. At the same time, control strategies designed to improve visibility in the national parks and wilderness areas are expected to improve visibility over broad geographic areas. For mobile sources, there is a need for a Federal role in reduction of those emissions, especially because mobile source engines are regulated primarily at the Federal level.

Because of evidence that fine particles are frequently transported hundreds of miles, all 50 states, including those that do not have mandatory Federal Class I areas, participate in planning, analysis, and, in many cases, emission control programs under the regional haze regulations. Virtually all of the 156 mandatory Federal Class I areas experience impaired visibility, requiring all States with those areas to prepare emission control programs to address it. Even though a given State may not have any mandatory Federal Class I areas, pollution that occurs in that State may contribute to impairment in such Class I areas elsewhere. The rule encourages states to work together to determine whether or how much emissions from sources in a given state affect visibility in a downwind mandatory Federal Class I area.

The regional haze program also calls for states to establish goals for improving visibility in national parks and wilderness areas to improve visibility on the haziest 20 percent of days and to ensure that no degradation occurs on the clearest 20 percent of days (64 FR 35722, July 1, 1999). The rule requires states to develop long-term strategies including enforceable measures designed to meet reasonable progress goals toward natural visibility conditions. Under the regional haze

[84] Technical Memorandum, EPA Air Docket A–99–06, Eric O. Ginsburg, Senior Program Advisor, Emissions Monitoring and Analysis Division, OAQPS, Summary of Absolute Modeled and Model-Adjusted Estimates of Fine Particulate Matter for Selected Years, December 6, 2000, Table P–2. Docket Number 2000–01, Document Number II-B–14.

program, States can take credit for improvements in air quality achieved as a result of other Clean Air Act programs, including national mobile source programs.[85]

In the PM air quality modeling described above, we also modeled visibility conditions in the mandatory Federal Class I areas, and we summarize the results by region in Table I.C–2. The information shows that these areas also are predicted to have high annual average deciview levels in the future. Emissions from nonroad land-based diesel engines and locomotive and marine engines contributed significantly to these levels, because these diesel engines represent a sizeable portion of the total inventory of anthropogenic emissions related to $PM_{2.5}$ (as shown in the tables above.). Furthermore, numerous types of nonroad engines may operate in or near mandatory Federal Class I areas (*e.g.*, mining, construction, and agricultural equipment). As summarized in the table, we expect visibility improvements in mandatory Federal Class I areas from the reductions of emissions from nonroad diesel engines subject to this proposed rule.

TABLE I.C–2—SUMMARY OF MODELED 2030 VISIBILITY CONDITIONS IN MANDATORY FEDERAL CLASS I AREAS

[Annual average deciview]

Region [a]	Predicted 2030 visibility baseline [b]	Predicted 2030 visibility with rule control [c]	Change in annual average deciviews
Eastern:			
Southeast	21.62	21.38	0.24
Northeast/Midwest	18.56	18.32	0.24
Western:			
Southwest	7.03	6.82	0.21
California	9.56	9.26	0.3
Rocky Mountain	8.55	8.34	0.21
Northwest	12.18	11.94	0.24
National Class I Area Average	11.8	11.56	0.24

Notes:

[a] Regions are depicted in Figure VI–5 in the Regulatory Support Document. Background visibility conditions differ by region: Eastern natural background is 9.5 deciviews (or visual range of 150 kilometers) and in the West natural background is 5.3 deciviews (or visual range of 230 kilometers).

[b] The results average visibility conditions for mandatory Federal Class I areas in the regions.

[c] The results illustrate the type of visibility improvements for the preliminary control option, as discussed in the draft RIA. The proposal differs based on updated information; however, we believe that the net results would approximate future PM emissions, although we anticipate the improvements would be slightly smaller.

2. Acid Deposition

Acid deposition, or acid rain as it is commonly known, occurs when SO_2 and NO_X react in the atmosphere with water, oxygen, and oxidants to form various acidic compounds that later fall to earth in the form of precipitation or dry deposition of acidic particles.[86] It contributes to damage of trees at high elevations and in extreme cases may cause lakes and streams to become so acidic that they cannot support aquatic life. In addition, acid deposition accelerates the decay of building materials and paints, including irreplaceable buildings, statues, and sculptures that are part of our nation's cultural heritage. To reduce damage to automotive paint caused by acid rain and acidic dry deposition, some manufacturers use acid-resistant paints, at an average cost of $5 per vehicle—a total of $80–85 million per year when applied to all new cars and trucks sold in the U.S.

Acid deposition primarily affects bodies of water that rest atop soil with a limited ability to neutralize acidic compounds. The National Surface Water Survey (NSWS) investigated the effects of acidic deposition in over 1,000 lakes larger than 10 acres and in thousands of miles of streams. It found that acid deposition was the primary cause of acidity in 75 percent of the acidic lakes and about 50 percent of the acidic streams, and that the areas most sensitive to acid rain were the Adirondacks, the mid-Appalachian highlands, the upper Midwest and the high elevation West. The NSWS found that approximately 580 streams in the Mid-Atlantic Coastal Plain are acidic primarily due to acidic deposition. Hundreds of the lakes in the Adirondacks surveyed in the NSWS have acidity levels incompatible with the survival of sensitive fish species. Many of the over 1,350 acidic streams in the Mid-Atlantic Highlands (mid-Appalachia) region have already experienced trout losses due to increased stream acidity. Emissions from U.S. sources contribute to acidic deposition in eastern Canada, where the Canadian government has estimated that 14,000 lakes are acidic. Acid deposition also has been implicated in contributing to degradation of high-elevation spruce forests that populate the ridges of the Appalachian Mountains from Maine to Georgia. This area includes national parks such as the Shenandoah and Great Smoky Mountain National Parks.

A study of emissions trends and acidity of water bodies in the Eastern U.S. by the General Accounting Office (GAO) found that from 1992 to 1999 sulfates declined in 92 percent of a representative sample of lakes, and nitrate levels increased in 48 percent of the lakes sampled.[87] The decrease in sulfates is consistent with emissions

[85] In a recent case, *American Corn Growers Association* v. *EPA,* 291 F. 3d 1 (D.C. Cir 2002), the court vacated the Best Available Retrofit Technology (BART) provisions of the Regional Haze rule, but the court denied industry's challenge to EPA's requirement that states' SIPs provide for reasonable progress towards achieving natural visibility conditions in national parks and wilderness areas and the ''no degradation'' requirement. Industry did not challenge requirements to improve visibility on the haziest 20 percent of days. A copy of this decision can be found in Docket A–2000–01, Document IV-A–113.

[86] Much of the information in this subsection was excerpted from the EPA document, Human Health Benefits from Sulfate Reduction, written under title IV of the 1990 Clean Air Act Amendments, U.S. EPA, Office of Air and Radiation, Acid Rain Division, Washington, DC 20460, November 1995. Available in Docket A–2000–01, Document No. II–A–32.

[87] Acid Rain: Emissions Trends and Effects in the Eastern United States, U.S. General Accounting Office, March, 2000 (GOA/RCED–00–47). Available in Docket A–99–06, Document No. IV–G–159.

trends, but the increase in nitrates is inconsistent with the stable levels of nitrogen emissions and deposition. The study suggests that the vegetation and land surrounding these lakes have lost some of their previous capacity to use nitrogen, thus allowing more of the nitrogen to flow into the lakes and increase their acidity. Recovery of acidified lakes is expected to take a number of years, even where soil and vegetation have not been ''nitrogen saturated,'' as EPA called the phenomenon in a 1995 study.[88] This situation places a premium on reductions of SO_x and especially NO_X from all sources, including nonroad diesel engines, in order to reduce the extent and severity of nitrogen saturation and acidification of lakes in the Adirondacks and throughout the U.S.

The SO_X and NO_X reductions from today's action will help reduce acid rain and acid deposition, thereby helping to reduce acidity levels in lakes and streams throughout the country and help accelerate the recovery of acidified lakes and streams and the revival of ecosystems adversely affected by acid deposition. Reduced acid deposition levels will also help reduce stress on forests, thereby accelerating reforestation efforts and improving timber production. Deterioration of our historic buildings and monuments, and of buildings, vehicles, and other structures exposed to acid rain and dry acid deposition also will be reduced, and the costs borne to prevent acid-related damage may also decline. While the reduction in sulfur and nitrogen acid deposition will be roughly proportional to the reduction in SO_X and NO_X emissions, respectively, the precise impact of today's action will differ across different areas.

3. Eutrophication and Nitrification

Eutrophication is the accelerated production of organic matter, particularly algae, in a water body. This increased growth can cause numerous adverse ecological effects and economic impacts, including nuisance algal blooms, dieback of underwater plants due to reduced light penetration, and toxic plankton blooms. Algal and plankton blooms can also reduce the level of dissolved oxygen, which can also adversely affect fish and shellfish populations.

In 1999, NOAA published the results of a five year national assessment of the severity and extent of estuarine eutrophication. An estuary is defined as the inland arm of the sea that meets the mouth of a river. The 138 estuaries characterized in the study represent more than 90 percent of total estuarine water surface area and the total number of U.S. estuaries. The study found that estuaries with moderate to high eutrophication conditions represented 65 percent of the estuarine surface area. Eutrophication is of particular concern in coastal areas with poor or stratified circulation patterns, such as the Chesapeake Bay, Long Island Sound, or the Gulf of Mexico. In such areas, the ''overproduced'' algae tends to sink to the bottom and decay, using all or most of the available oxygen and thereby reducing or eliminating populations of bottom-feeder fish and shellfish, distorting the normal population balance between different aquatic organisms, and in extreme cases causing dramatic fish kills.

Severe and persistent eutrophication often directly impacts human activities. For example, losses in the nation's fishery resources may be directly caused by fish kills associated with low dissolved oxygen and toxic blooms. Declines in tourism occur when low dissolved oxygen causes noxious smells and floating mats of algal blooms create unfavorable aesthetic conditions. Risks to human health increase when the toxins from algal blooms accumulate in edible fish and shellfish, and when toxins become airborne, causing respiratory problems due to inhalation. According to the NOAA report, more than half of the nation's estuaries have moderate to high expressions of at least one of these symptoms—an indication that eutrophication is well developed in more than half of U.S. estuaries.

In recent decades, human activities have greatly accelerated nutrient inputs, such as nitrogen and phosphorous, causing excessive growth of algae and leading to degraded water quality and associated impairments of freshwater and estuarine resources for human uses.[89] Since 1970, eutrophic conditions worsened in 48 estuaries and improved in 14. In 26 systems, there was no trend in overall eutrophication conditions since 1970.[90] On the New England coast, for example, the number of red and brown tides and shellfish problems from nuisance and toxic plankton blooms have increased over the past two decades, a development thought to be linked to increased nitrogen loadings in coastal waters. Long-term monitoring in the U.S., Europe, and other developed regions of the world shows a substantial rise of nitrogen levels in surface waters, which are highly correlated with human-generated inputs of nitrogen to their watersheds.

Between 1992 and 1997, experts surveyed by National Oceanic and Atmospheric Administration (NOAA) most frequently recommended that control strategies be developed for agriculture, wastewater treatment, urban runoff, and atmospheric deposition.[91] In its Third Report to Congress on the Great Waters, EPA reported that atmospheric deposition contributes from 2 to 38 percent of the nitrogen load to certain coastal waters.[92] A review of peer reviewed literature in 1995 on the subject of air deposition suggests a typical contribution of 20 percent or higher.[93] Human-caused nitrogen loading to the Long Island Sound from the atmosphere was estimated at 14 percent by a collaboration of Federal and State air and water agencies in 1997.[94] The National Exposure Research Laboratory, U.S. EPA, estimated based on prior studies that 20 to 35 percent of the nitrogen loading to the Chesapeake Bay is attributable to atmospheric deposition.[95] The mobile source portion of atmospheric NO_X contribution to the Chesapeake Bay was modeled at about 30 percent of total air deposition.[96]

Deposition of nitrogen from nonroad diesel engines contributes to elevated nitrogen levels in waterbodies. The proposed standards for nonroad diesel

[88] Acid Deposition Standard Feasibility Study: Report to Congress, EPA 430R–95–001a, October, 1995.

[89] Deposition of Air Pollutants to the Great Waters, Third Report to Congress, June, 2000. Available in Docket A–99–06, Document No. IV–A–06.

[90] Deposition of Air Pollutants to the Great Waters, Third Report to Congress, June, 2000. Great Waters are defined as the Great Lakes, the Chesapeake Bay, Lake Champlain, and coastal waters. The first report to Congress was delivered in May, 1994; the second report to Congress in June, 1997. Available in Docket A–99–06, Document No. IV–A–06.

[91] Bricker, Suzanne B., *et al.*, National Estuarine Eutrophication Assessment, Effects of Nutrient Enrichment in the Nation's Estuaries, National Ocean Service, National Oceanic and Atmospheric Administration, September, 1999. Available in Docket A–99–06, Document No. IV–G–145.

[92] Deposition of Air Pollutants to the Great Waters, Third Report to Congress, June, 2000. Available in Docket A–99–06, Document No. IV–A–06.

[93] Valigura, Richard, *et al.*, Airsheds and Watersheds II: A Shared Resources Workshop, Air Subcommittee of the Chesapeake Bay Program, March, 1997. Available in Docket A–99–06, Document No. IV–G–144.

[94] The Impact of Atmospheric Nitrogen Deposition on Long Island Sound, The Long Island Sound Study, September, 1997.

[95] Dennis, Robin L., Using the Regional Acid Deposition Model to Determine the Nitrogen Deposition Airshed of the Chesapeake Bay Watershed, SETAC Technical Publications Series, 1997.

[96] Dennis, Robin L., Using the Regional Acid Deposition Model to Determine the Nitrogen Deposition Airshed of the Chesapeake Bay Watershed, SETAC Technical Publications Series, 1997.

engines will reduce total NO_X emissions by 831,000 tons in 2030. The NO_X reductions will reduce the airborne nitrogen deposition that contributes to eutrophication of watersheds, particularly in aquatic systems where atmospheric deposition of nitrogen represents a significant portion of total nitrogen loadings.

4. Polycyclic Organic Matter Deposition

EPA's Great Waters Program has identified 15 pollutants whose deposition to water bodies has contributed to the overall contamination loadings to the these Great Waters.[97] One of these 15 pollutants, a group known as polycyclic organic matter (POM), are compounds that are mainly adhered to the particles emitted by mobile sources and later fall to earth in the form of precipitation or dry deposition of particles. The mobile source contribution of the 7 most toxic POM is at least 62 tons/year and represents only those POM that adhere to mobile source particulate emissions.[98] The majority of these emissions are produced by diesel engines.

The PM reductions from this proposed action will help reduce not only the PM emissions from nonroad diesel engines but also the deposition of the POM adhering to the particles, thereby helping to reduce health effects of POM in lakes and streams, accelerate the recovery of affected lakes and streams, and revive the ecosystems adversely affected.

5. Plant Damage From Ozone

Ground-level ozone can also cause adverse welfare effects. Specifically, ozone enters the leaves of plants where it interferes with cellular metabolic processes. This interference can be manifest either as visible foliar injury from cell injury or death, and/or as decreased plant growth and yield due to a reduced ability to produce food. With fewer resources, the plant reallocates existing resources away from root storage, growth and reproduction toward leaf repair and maintenance. Plants that are stressed in these ways become more susceptible to disease, insect attack, harsh weather and other environmental stresses. Because not all plants are equally sensitive to ozone, ozone pollution can also exert a selective pressure that leads to changes in plant community composition.

Since plants are at the center of the food web in many ecosystems, changes to the plant community can affect associated organisms and ecosystems (including the suitability of habitats that support threatened or endangered species and below ground organisms living in the root zone). Given the range of plant sensitivities and the fact that numerous other environmental factors modify plant uptake and response to ozone, it is not possible to identify threshold values above which ozone is toxic and below which it is safe for all plants. However, in general, the science suggests that ozone concentrations of 0.10 ppm or greater can be phytotoxic to a large number of plant species, and can produce acute foliar injury responses, crop yield loss and reduced biomass production. Ozone concentrations below 0.10 ppm (0.05 to 0.09 ppm) can produce these effects in more sensitive plant species, and have the potential over a longer duration of creating chronic stress on vegetation that can lead to effects of concern such as reduced plant growth and yield, shifts in competitive advantages in mixed populations, and decreased vigor leading to diminished resistance to pests, pathogens, and injury from other environmental stresses.

Studies indicate that these effects described here are still occurring in the field under ambient levels of ozone. The economic value of some welfare losses due to ozone can be calculated, such as crop yield loss from both reduced seed production (*e.g.*, soybean) and visible injury to some leaf crops (*e.g.*, lettuce, spinach, tobacco) and visible injury to ornamental plants (*i.e.*, grass, flowers, shrubs), while other types of welfare loss may not be fully quantifiable in economic terms (*e.g.*, reduced aesthetic value of trees growing in Class I areas).

As discussed above, nonroad diesel engine emissions of VOCs and NO_X contribute to ozone. This proposed rule would reduce ozone and, therefore, help to reduce crop damage and stress from ozone on vegetation. *See* the draft RIA for a more detailed discussion of the science of these effects.

D. Other Criteria Pollutants Affected by This NPRM

The standards being proposed today would also help reduce levels of other pollutants for which NAAQS have been established: carbon monoxide (CO), nitrogen dioxide (NO_2), and sulfur dioxide (SO_2). Currently every area in the United States has been designated to be in attainment with the NO_2 NAAQS. As of November 4, 2002, there were 24 areas designated as non-attainment with the SO_2 standard, and 14 designated CO non-attainment areas.

The current primary NAAQS for CO are 35 parts per million for the one-hour average and 9 parts per million for the eight-hour average. These values are not to be exceeded more than once per year. Over 22 million people currently live in the 14 non-attainment areas for the CO NAAQS. *See* the draft RIA for a detailed discussion of the emission benefits of this proposed rule.

Carbon monoxide is a colorless, odorless gas produced through the incomplete combustion of carbon-based fuels. Carbon monoxide enters the bloodstream through the lungs and reduces the delivery of oxygen to the body's organs and tissues. The health threat from CO is most serious for those who suffer from cardiovascular disease, particularly those with angina or peripheral vascular disease. Healthy individuals also are affected, but only at higher CO levels. Exposure to elevated CO levels is associated with impairment of visual perception, work capacity, manual dexterity, learning ability and performance of complex tasks.

Land-based nonroad engines contributed about one percent of CO from mobile sources in 1996. EPA previously determined that the category of nonroad diesel engines cause or contribute to ambient CO and ozone in more than one non-attainment area (65 FR 76790, December 7, 2000). In that action EPA found that nonroad engines contribute to CO non-attainment in areas such as Los Angeles, Phoenix, Spokane, Anchorage, and Las Vegas. Nonroad land-based diesel engines emitted 927,500 tons of CO in 1996 (1% of mobile source CO).

E. Emissions From Nonroad Diesel Engines

Emissions from nonroad diesel engines will continue to be a significant part of the emissions inventory in the coming years. In the absence of new emission standards, we expect overall emissions from nonroad diesel engines subject to this proposal to generally decline across the nation for the next 10 to 15 years, depending on the pollutant.[99] Although nonroad diesel engine emissions will decline during this period, this trend will not be enough to adequately reduce the large amount of emissions that these engines contribute. For example, the declines are insufficient to prevent significant

[97] Deposition of Air Pollutants to the Great Waters-Third Report to Congress, June, 2000, Office of Air Quality Planning and Standards Deposition of Air Pollutants to the Great Waters-Second Report to Congress, Office of Air Quality Planning and Standards, June 1997, EPA–453/R–97–011. Available in Docket A–99–06, Document No. IV–A–06.

[98] The 1996 National Toxics Inventory, Office of Air Quality Planning and Standards, October 1999.

[99] As defined here, nonroad diesel engines include land-based, locomotive, commercial marine vessel, and recreational marine engines.

contributions to nonattainment of $PM_{2.5}$ and ozone NAAQS, or to prevent widespread exposure to significant concentrations of nonroad engine air toxics. In addition, after the 2010 to 2015 time period we project that this trend reverses and emissions rise into the future in the absence of additional regulation of these engines. (This phenomenon is further described later in this section.) The initial downward trend occurs as the nonroad fleet becomes increasingly dominated over time by engines that comply with existing emission regulations. The upturn in emissions beginning around 2015 results as growth in the nonroad sector overtakes the effect of the existing emission standards.

The engine and fuel standards in this proposal will affect fine particulate matter ($PM_{2.5}$), oxides of nitrogen (NO_X), sulfur oxides (SO_2), volatile organic hydrocarbons (VOC), and air toxics. For locomotive, commercial marine vessel (CMV), and recreational marine vessel (RMV) engines, the proposed fuel standards will affect $PM_{2.5}$ and SO_2. CO is not specifically targeted in this proposal but its reductions are discussed in the draft RIA.[100]

Each sub-section within section II discusses the emissions of a pollutant that the proposal addresses.[101] This is followed by a discussion of the expected emission reductions associated with the proposed standards for land-based nonroad diesel engines.[102] The tables and figures illustrate the Agency's projection of future emissions from nonroad diesel engines for each pollutant.[103] The baseline case represents future emissions from land-based nonroad diesel engines with current standards. The controlled case estimates the future emissions of these engines based on the proposed standards in this notice.

1. $PM_{2.5}$

As described earlier in this section of the preamble, the Agency believes that reductions of diesel $PM_{2.5}$ emissions are needed as part of the Nation's progress toward clean air and to reach attainment of the NAAQS for $PM_{2.5}$. The nonroad engines controlled by this proposal are the major sources of nonroad diesel emissions. Table II.E–1 shows that the PM2.5 emissions from land-based nonroad diesels amount to increasingly large percentages of total manmade diesel $PM_{2.5}$ in the years 1996, 2020 and 2030.[104] [105]

TABLE II.E–1—BASE-CASE NATIONAL (48 STATE) DIESEL $PM_{2.5}$

(Short tons)

Year	Total diesel $PM_{2.5}$	Nonroad land-based diesel $PM_{2.5}$	Nonroad land-based percent of total diesel $PM_{2.5}$ (percent)
1996	414,000	177,000	43
2020	206,000	124,000	60
2030	220,000	140,000	64

The contribution of land-based nonroad CI engines to PM2.5 inventories can be significant, especially in densely populated urban areas.[106] As illustrated in Table II.E.-2, our city-specific analysis of selected metropolitan areas for 1996 and 2020 shows that the land-based nonroad diesel engine contribution to total $PM_{2.5}$ ranges up to 18 percent in 1996 and 19 percent in 2020.[107]

TABLE II.E–2—BASELINE LAND-BASED NONROAD DIESEL PERCENT CONTRIBUTION TO $PM_{2.5}$ INVENTORIES IN SELECTED URBAN AREAS IN 1996 AND 2020

MSA, State	Land-Based Nonroad $PM_{2.5}$ Contribution to Total $PM_{2.5}$[a] in 1996	Land-Based Nonroad $PM_{2.5}$ Contribution to Total $PM_{2.5}$[a] in 2020
Atlanta, GA	7	6
Boston, MA	18	18
Chicago, IL	8	7
Dallas-Ft. Worth, TX	13	10
Indianapolis, IN	15	13
Minneapolis-St. Paul, MN	10	8
New York, NY	13	12
Orlando, FL	14	12
Sacramento, CA	7	7
San Diego, CA	9	7
Denver, CO	11	8
El Paso, TX	15	19
Las Vegas, NV	15	12
Phoenix-Mesa, AZ	15	12
Seattle, WA	7	7
National Average[b]	8	6

[a] Includes only direct exhaust diesel emissions; see Section II.C for a discussion of secondary fine PM levels.
[b] This is a 48 state national average.

Emissions of $PM_{2.5}$ from land-based nonroad diesel engines based on a 50 state inventory are shown in Table II.E–3, along with our estimates of the reductions in 2020 and 2030 we expect would result from our proposal for a $PM_{2.5}$ exhaust emission standard and changes in the sulfur level in nonroad diesel fuel. For comparison purposes, $PM_{2.5}$ emissions based on lowering nonroad diesel fuel sulfur levels to about 340 ppm in-use[108] (500 ppm maximum) without any other controls are shown, along with the estimated emissions with the proposed $PM_{2.5}$ standard and a sulfur level of 11 ppm in-use (15 ppm maximum). Figure II.E–1 shows our estimate of $PM_{2.5}$ emissions between 2000 and 2030 both without

[100] We are proposing only a few minor adjustments of a technical nature to current CO standards.

[101] The estimates of baseline emissions and emissions reductions from the proposed rule reported here for nonroad land-based, recreational marine, locomotive, and commercial marine vessel diesel engines are based on 50 state emissions inventory estimates. However, 50 state emissions inventory data are not available for other emission sources. Thus, emissions estimates for other sources are based on a 48 state inventory that excludes Alaska and Hawaii. The 48 state inventory was done for air quality modeling that EPA uses to analyze regional ozone transport, of which Alaska and Hawaii are not a part. In cases where land-based nonroad diesel engine emissions are summed or compared with other emissions sources, we use a 48 state emissions inventory.

[102] For the purpose of this proposal, land-based nonroad diesel engines include engines used in equipment modeled by the draft NONROAD emissions model, except for recreational marine engines. Recreational marine diesel engines are not subject to the exhaust emission standards contained in this proposal but would be affected by the fuel sulfur requirements applicable to locomotive and commercial marine vessel engines.

[103] The air quality modeling results described in sections II.B and II.C use a slightly different emissions inventory based on earlier, preliminary modeling assumptions. Chapter 3 of the draft RIA and the technical support documents fully describe this inventory, as well as the differences between it and the inventory reflecting the proposal.

[104] Nitrate and sulfate secondary fine particulate as described in section II.B and are not included in the values reported here or elsewhere, but are discussed in the Regulatory Impact Analysis, chapter X.

[105] As a function of the available national inventories from other sources, we are only able to present a 48-state inventory. Wherever possible we present a 50-state inventory.

[106] Construction, industrial, and commercial nonroad diesel equipment comprise most of the land-based nonroad emissions inventory. These types of equipment are more concentrated in urban areas where construction projects, manufacturing, and commercial operations are prevalent. For more information, please refer to the report, ''Geographic Allocation of State Level Nonroad Engine Population Data to the County Level,'' NR–014b, EPA 420–P–02–009.

[107] We selected these cities to show a collection of typical cities spread across the United States in order to compare typical urban inventories with national average ones.

[108] This value (340 ppm) represents the average in-use sulfur concentration of fuel produced to meet a 500 ppm sulfur standard. In practice, off-highway equipment will sometimes be refueled with diesel fuel meeting the more stringent highway standard of 15 ppm. Therefore, the actual average in-use sulfur level of the fuel used by off-highway equipment will be somewhat lower than 340 ppm. The emission benefits shown here reflect this lower in-use sulfur level.

and with the proposed $PM_{2.5}$ standard (along with an assumed sulfur level of 11 ppm in-use, 15 ppm maximum). By 2030, we estimate that $PM_{2.5}$ emissions from this source would be reduced by 86 percent in that year.

TABLE II.E–3.—ESTIMATED NATIONAL (50 STATE) REDUCTIONS IN $PM_{2.5}$ EMISSIONS FROM NONROAD LAND-BASED, LOCOMOTIVE, COMMERCIAL MARINE, AND RECREATIONAL MARINE DIESEL ENGINES

Year	$PM_{2.5}$* without rule [short tons]	$PM_{2.5}$ with 500 ppm fuel sulfur (340 in-use) and no other controls [short tons]	$PM_{2.5}$ reductions with 500 ppm fuel sulfur (340 in-use) and no other controls [short tons]	$PM_{2.5}$ with rule (15 ppm sulfur level, 11 in-use) [short tons]	$PM_{2.5}$ reductions with rule (15 ppm sulfur level, 11 in-use) [short tons]
2020	186,000	163,000	100,000	23,000	86,000
2030	205,000	178,000	77,000	27,000	127,000

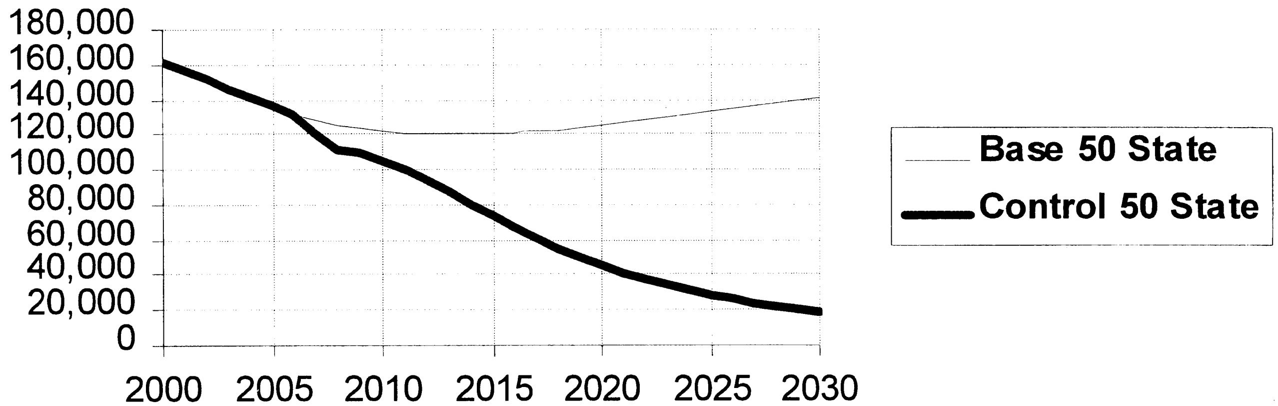

Figure II.E-1: Estimated Reductions in PM2.5 Emissions From Land-Based Nonroad Diesel Engines (tons/year)

Nonroad diesel engines used in locomotives, commercial marine vessels, and recreational marine vessels are not affected by the emission standards of this proposal. $PM_{2.5}$ emissions from these engines would be reduced by the reductions in diesel fuel sulfur for these types of engines from an in-use average of between 2,300 and 2,400 ppm today to an in-use average of about 340 ppm (500 ppm maximum) in 2007. The estimated reductions in $PM_{2.5}$ emissions from these engines based on the proposed change in diesel fuel sulfur are about 6,000 tons in 2020 and 7,000 tons in 2030.[109] For more information on proposed fuel sulfur reductions, please *see* chapter 7 of the draft RIA.

2. NO_X

Table II.E–4 shows the 50 state estimated tonnage of NO_X emissions for 2020 and 2030 without the proposed rule and the estimated tonnage of emissions eliminated with the proposed rule in place. These results are shown graphically in Figure II.E–2. By 2030, we estimate that NO_X emissions from these engines will be reduced by 67 percent in that year.

TABLE II.E.–4.—ESTIMATED NATIONAL (50 STATE) REDUCTIONS IN NO_X EMISSIONS FROM NONROAD LAND-BASED DIESEL ENGINES

Calendar year	NO_X without rule [short tons]	NO_X with rule [short tons]	NO_X reductions with rule [short tons]
2020	1,147,000	640,000	507,000
2030	1,239,000	412,000	827,000

[109] These reductions are based on a 50 state emissions inventory estimate.

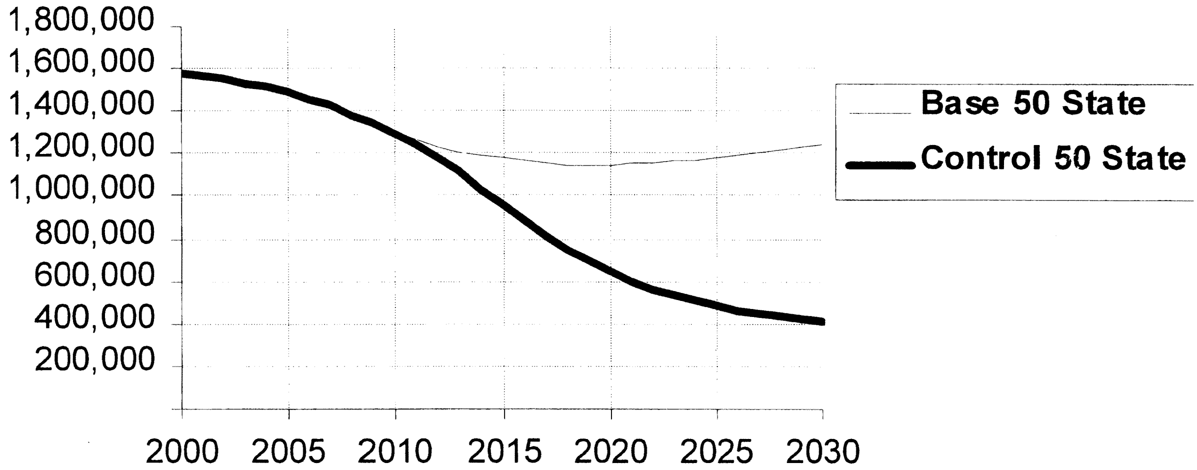

Figure II.E-2: Estimated Reductions in NOx Emissions From Land-Based Nonroad Diesel Engines (tons/year)

Table E.II–5 shows that the engines affected by the proposal emit a significant portion of total NO_X emissions in 1996 and 2020, especially in cities. This is not surprising given the high density of these engines operating in urban areas.[110] We selected a variety of cities from across the nation and found that these engines contribute up to 14 percent of the total NO_X inventories in 1996 and as much as 20 percent to total NO_X inventories in 2020.[111]

TABLE II.E–5—BASELINE LAND-BASED NONROAD DIESEL PERCENT CONTRIBUTION TO NO_X INVENTORIES IN SELECTED URBAN AREAS IN 2020

MSA, State	Land-based NR NO_X as percentage of total NO_X in 1996	Land-based NR NO_X as percentage of total NO_X in 2020
Atlanta, GA	5	7
Boston, MA	14	19
Chicago, IL	6	7
Dallas-Fort Worth, TX	10	13
Indianapolis, IN	8	12
Minneapolis-St. Paul, MN	6	6
New York, NY	11	20
Orlando, FL	10	13
Sacramento, CA	10	19
San Diego, CA	9	14
Denver, CO	8	8
El Paso, TX	8	15
Las Vegas, NV–AZ	11	12
Phoenix-Mesa, AZ	9	11
Seattle, WA	8	11
National Average[a]	6	7

[a] This is a 48 state national average.

3. SO_2

We estimate that land-based nonroad, CMV, RMV, and locomotive diesel engines emitted about 227,000 tons of SO_2 in 1996, accounting for about 30 percent of the SO_2 from mobile sources (based on a 48 state inventory). With no reduction in diesel fuel sulfur levels, we estimate that these emissions will continue to increase, accounting for about 60 percent of mobile source SO_2 emissions by 2030.

As part of this proposal, sulfur levels in fuel would be significantly reduced, leading to large reductions in nonroad diesel SO_2 emissions. By 2007, the sulfur in diesel fuel used by all nonroad diesel engines would be reduced from the current average in-use level of between 2,300 and 2,400 ppm to an average in-use level of about 340 ppm with a maximum level of 500 ppm. By 2010, the sulfur in diesel fuel used by land-based nonroad engines would be

[110] Construction, industrial, and commercial nonroad diesel equipment comprise most of the land-based nonroad emissions inventory. These types of equipment are more concentrated in urban areas where construction projects, manufacturing, and commercial operations are prevalent. For more information, please refer to the report, "Geographic Allocation of State Level Nonroad Engine Population Data to the County Level," NR–014b, EPA 420–P–02–009.

[111] We selected these cities to show a collection of typical cities spread across the United States in order to compare typical urban inventories with national average ones.

reduced to an average in-use level of 11 ppm with a maximum level of 15 ppm. The sulfur in diesel fuel used by locomotives, CMVs, and RMVs would remain at an average in-use level of about 340 ppm. Figure II.E–3 shows the estimated reductions from these sulfur changes. For more information on this topic, please *see* chapter 7 of the RIA.[112]

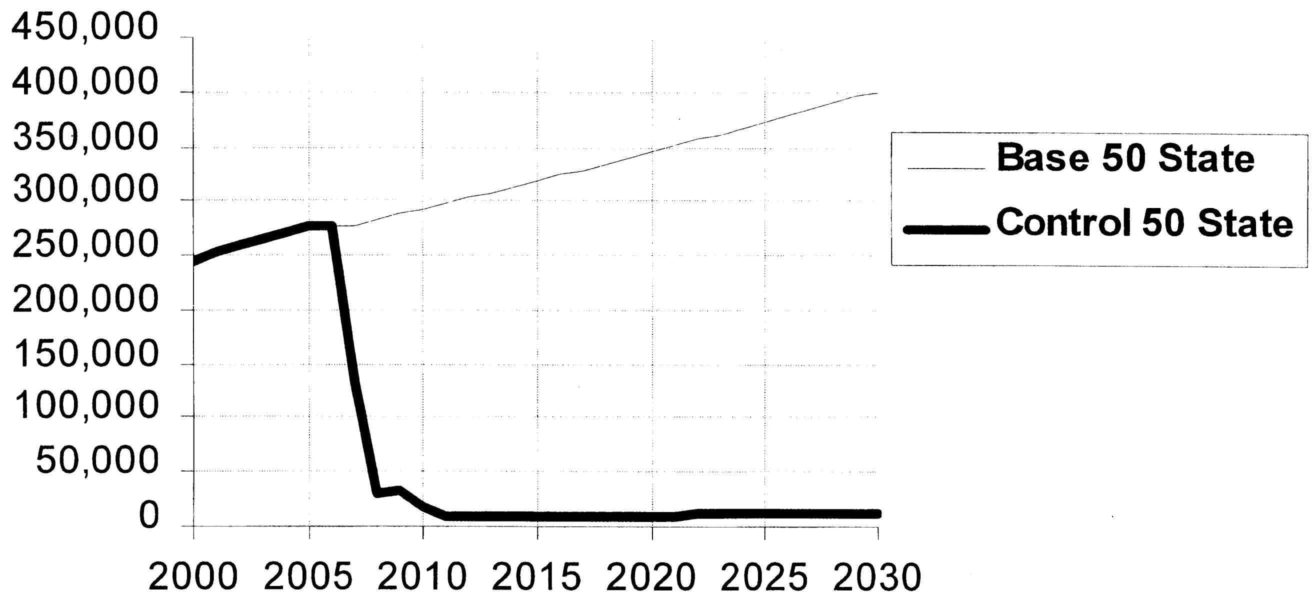

Figure II.E-3: Estimated SO_2 Reductions From Reducing Diesel Sulfur For Land-Based Nonroad Engines, CMVs, RMVs, and Locomotives (tons/year)

Table II.E–6 shows 50 state estimates of total SO_2 emissions without the proposed rule and how SO_2 emissions would be reduced by the diesel fuel sulfur reductions in 2020 and 2030.

Lowering diesel fuel sulfur to a maximum of 500 ppm (340 ppm in-use) for CMV, locomotive and land-based nonroad engines would result in a reduction of about 360,000 tons/year of SO_2 in 2030. Lowering diesel fuel sulfur to a maximum of 500 ppm (340 ppm in-use) for CMV and locomotive engines and a maximum of 15 ppm (11 ppm in-use) for land-based nonroad engines would result in a reduction of about 390,000 tons of SO_2 in 2030.

TABLE II.E–6—ESTIMATED NATIONAL (50 STATE) EMISSIONS OF LAND-BASED NONROAD, LOCOMOTIVE, COMMERCIAL MARINE VESSEL, AND RECREATIONAL MARINE VESSEL

[SO_2 Emissions From Lowering Diesel Fuel Sulfur Levels]

Year	Total SO_2 emissions at 2400 ppm sulfur without proposed rule [short tons]	500 ppm sulfur (340 ppm in-use) locomotives, CMVs, RMVs[a] [short tons]	500 ppm sulfur (340 in-use) land-based nonroad [short tons]	15 ppm sulfur (11 ppm in-use) land-based nonroad [short tons]
1996	229,000			
2020	345,000	9,000	26,000	1,000
2030	401,000	10,000	30,000	1,000

Notes:
[a] CMV = commercial marine vessels, RMV = Recreational marine vessels.

4. VOC and Air Toxics

Based on a 48 state emissions inventory, we estimate that land-based nonroad diesel engines emitted over 221 thousand tons of VOC in 1996. Between 1996 and 2030, we estimate that land-based nonroad diesel engines will contribute about 2 to 3 percent to mobile source VOC emissions. Without further controls, land-based nonroad diesel engines will emit over 97

[112] Under this proposal, the introduction of 340 ppm (approximate average in-use level, 500 ppm maximum) sulfur diesel fuel for all nonroad diesel engines would take place in June of 2007. The introduction of 11 ppm sulfur diesel fuel (average in-use, 15 ppm maximum) for land-based nonroad engines would take place in June 2010.

thousand tons/year of VOC in 2020 and 2030 nationally.[113]

Tables II.E–7 shows our projection of the reductions in 2020 and 2030 for VOC emissions that we expect from implementing the proposed NMHC standards. This estimate is based on a 50 state emissions inventory. By 2030, VOC reductions would be reduced by 30 percent.

TABLE II.E–7—ESTIMATED NATIONAL (50 STATE) REDUCTIONS IN VOC EMISSIONS FROM NONROAD LAND-BASED DIESEL ENGINES

Calendar year	VOC without rule [short tons]	VOC with rule [short tons]	VOC reductions with rule [short tons]
2020	97,000	79,000	18,000
2030	98,000	68,000	30,000

Air toxics pollutants are in VOCs and are included in the total land-based nonroad diesel VOC emissions estimate. We base these numbers on the assumption that air toxic emissions are a constant fraction of hydrocarbon exhaust emissions.

Although we are not proposing any specific gaseous air toxics standards, air toxics emissions would nonetheless be reduced through NMHC standards included in the proposed rule. By 2030, we estimate that emissions of air toxics pollutants, such as benzene, formaldehyde, acetaldehyde, 1,3-butadiene, and acrolein, would be reduced by 30 percent from land-based nonroad diesel engines. For specific air toxics reductions please see chapter 3 of the RIA. In section II.B.2 we discuss the health effects of these pollutants.

III. Nonroad Engine Standards

In this section we describe the nonroad diesel emission standards we are proposing in order to address the serious air quality problems discussed in section II. Specifically, we discuss:

- The Clean Air Act and why we are proposing new emission standards.
- The technology opportunity for nonroad diesel emissions control.
- Our proposed engine standards, and our proposed schedule for implementing them.
- Proposals for supplemental test procedures and standards to help control emissions during transient operating modes and engine start-up.
- Proposals to help ensure robust emissions control in use.
- The feasibility of the proposed standards (in conjunction with the proposed low-sulfur nonroad diesel fuel requirement discussed in section IV).
- How diesel fuel sulfur affects an engine's ability to meet the proposed standards.
- Plans for a future reassessment of the technology needed to comply with proposed standards for engines below 75 hp.

Additional proposed provisions for engine and equipment manufacturers are discussed in detail in section VII. Briefly, these include changes to our engine manufacturer averaging, banking, and trading (ABT) program, changes to our transition program for equipment manufacturers, special provisions to aid small businesses in implementing our requirements, and an incentive program to encourage innovative technologies and the early introduction of new technologies.

We welcome comment on all facets of this discussion, including the levels and timing of the proposed emissions standards and our assessment of technological feasibility, as well as on the supporting analyses contained in the Draft Regulatory Impact Analysis (RIA). We also request comment on the timing of the proposed diesel fuel standard in conjunction with these proposed emission standards. We ask that commenters provide any technical information that supports the points made in their comments.

A. Why Are We Setting New Engine Standards?

1. The Clean Air Act and Air Quality

We believe that Agency action is needed to address the air quality problems discussed in section II. We are therefore proposing new engine standards and related provisions under sections 213(a)(3) and (4) of the Clean Air Act which, among other things, direct us to establish (and from time to time revise) emission standards for new nonroad diesel engines. Because emissions from these engines contribute greatly to a number of serious air pollution problems, especially the health and welfare effects of ozone, PM, and air toxics, we believe that the air quality need for stringent nonroad diesel standards is well established. This, and our belief that a significant degree of emission reduction from these engines is achievable through the application of diesel emission control technology that will be available in the lead time provided (giving appropriate consideration to cost, noise, safety, and energy factors as required by the Act), along with coordinated reductions in nonroad diesel fuel sulfur levels, leads us to believe that these new emission standards are warranted and appropriate.

We also believe that the proposed engine standards are consistent with the Clean Air Act section 213 requirements on availability of technology and appropriate lead time. The basis for our conclusion is described in this section and in the Draft RIA.

2. The Technology Opportunity for Nonroad Diesel Engines

Substantial progress has been made in recent years in controlling diesel exhaust emissions through the use of robust, high-efficiency catalytic devices placed in the exhaust system. Particularly promising are the catalytic soot filter or particulate trap for PM and hydrocarbon control, and the NO_X adsorber. These technologies are expected to be applied to highway heavy-duty diesel engines (HDDEs) beginning in 2007 to meet stringent new standards for these engines. The final EPA rule establishing those standards contains extensive discussion of how these devices work, how effective they are at reducing emissions, and what their limitations are, particularly their dependence on very-low sulfur diesel fuel to function properly (66 FR 5002, January 18, 2001; *see* especially section III of the preamble starting at 5035). Reviews of ongoing progress in the development of these technologies have recently been performed by EPA and by

[113] VOC emissions remain about the same in 2030 as 2020 because while nonroad diesel emission factors decrease and newer engines continue to be introduced into the fleet, the engine/equipment population continues to increase. The increase in engine/equipment population offsets the effect of decreasing emission factors.

an independent review panel.[114] [115] These reviews found that significant progress has been made since the final rule was published, reinforcing our confidence that the highway engine standards can be met. (Our consideration of these highway engine standards is consistent with the requirement in Clean Air Act section 213(a)(3) that EPA consider nonroad engine standards equivalent in stringency to those adopted for comparable highway engines regulated under section 202 of the Act.)

Although there are important differences, nonroad diesel engines operate fundamentally like heavy-duty highway diesel engines. In fact, many nonroad engine designs are derived from highway engine platforms. We believe that, given the availability of nonroad diesel fuel meeting our proposed 15 ppm maximum sulfur requirement and adequate development lead time, nonroad diesel engines can be designed to successfully employ the same high-efficiency exhaust emission control technologies now being developed for highway use. Indeed, some nonroad diesel applications, such as in underground mining, have pioneered the use of similar technologies for many years. These technologies, the experience gained with them in nonroad applications, the issues involved in transferring technology from highway to nonroad applications, and the appropriate standards and test procedures for this nonroad Tier 4 program are discussed in detail in the remainder of this section.

B. What Engine Standards Are We Proposing?

1. Exhaust Emissions Standards

The PM, NO_X, and NMHC emissions standards being proposed for nonroad diesel engines are summarized in Figures III.B–1 and 2. We are also making minor adjustments to CO standards as discussed in section III.B.1.f. All of these standards would apply to covered nonroad engines over the useful life periods specified in our regulations, except where temporary in-use compliance margins would apply as discussed in section VII.J.[116] We are not proposing changes to the current useful life periods because we do not have any relevant new information that would lead us to propose changes. However, we do ask for comment on whether or not changes are warranted and, if so, on what the useful life periods should be. The testing requirements by which compliance with the standards would be measured are discussed in section III.C. In addition we are proposing new ''not-to-exceed'' (NTE) emission standards and associated test procedures to help ensure robust control of emissions in use. These standards are discussed as part of a broader outline of proposed NTE provisions in sections III.D and VII.G.

FIGURE III.B–1—PROPOSED PM STANDARDS (G/BHP-HR) AND SCHEDULE

Engine Power	Model Year					
	2008	2009	2010	2011	2012	2013
hp < 25 (kW < 19)	[a] 0.30					
25 ≤ hp < 75 (19 ≤ kW < 56)	[b] 0.22					0.02
75 ≤ hp < 175 (56 ≤ kW < 130)					0.01	
175 ≤ hp ≤ 750 (130 ≤ kW ≤ 560)				0.01		
hp > 750 (kW > 560)				[c] 0.01		

Notes:

[a] For air-cooled, hand-startable, direct injection engines under 11 hp, a manufacturer may instead delay implementation until 2010 and demonstrate compliance with a less stringent PM standard of 0.45 g/bhp-hr, subject also to additional provisions discussed in Section III.B.1.d.i.

[b] A manufacturer has the option of skipping the 0.22 g/bhp-hr PM standard for all 50–75 hp engines; the 0.02 g/bhp-hr PM standard would then take effect one year earlier for all 50–75 hp engines (in 2012).

[c] 50% of a manufacturer's U.S.-directed production must meet the 0.01 g/bhp-hr PM standard in this model year. In 2014, 100% must comply.

FIGURE III.B–2—PROPOSED NO_X AND NMHC STANDARDS AND SCHEDULE

Engine Power	Standard (g/bhp-hr)	
	NO_X	NMHC
25 ≤ hp < 75 (19 ≤ kW < 56)	3.5 NMHC+NO_X [a]	
75 ≤ hp < 175 (56 ≤ kW < 130)	0.30	0.14
175 ≤ hp ≤ 750 (130 ≤ kW ≤ 560)	0.30	0.14
hp > 750 (kW > 560)	0.30	0.14

Engine Power	Phase-in Schedule			
	2011	2012	2013	2014
25 ≤ hp < 75 (19 ≤ kW < 56)			100%	
75 ≤ hp < 175 (56 ≤ kW < 130)		[b] 50%	[b] 50%	[b] 100%
175 ≤ hp ≤ 750 (130 ≤ kW ≤ 560)	50%	50%	50%	100%
hp > 750 (kW > 560)	50%	50%	50%	100%

Notes:

Percentages are U.S.-directed production required to comply with the Tier 4 standards in the indicated model year.

[a] This is the existing Tier 3 combined NMHC+NO_X standard level for the 50–75 hp engines in this category; in 2013 it would apply to the 25–50 hp engines as well.

[114] ''Highway Diesel Progress Review'', U.S. EPA, June 2002. EPA420-R–02–016. (*www.epa.gov/air/caaac/dieselreview.pdf*).

[115] ''Meeting Technology Challenges For the 2007 Heavy-Duty Highway Diesel Rule'', Final Report of the Clean Diesel Independent Review Subcommittee, Clean Air Act Advisory Committee, October 30, 2002. (*www.epa.gov/air/caaac/diesel/finalcdirpreport103002.pdf*).

[116] The useful life for engines ≥50 hp is 8,000 hours or 10 years, whichever occurs first. For engines <25 hp, and for 25–50 hp engines that operate at constant speed at or above 3000 rpm, it is 3000 hours or 5 years. For other 25–50 hp engines, it is 5,000 hours or 7 years.

[b] Manufacturers may use banked Tier 2 NMHC+NO_X credits to demonstrate compliance with the proposed 75–175 hp engine NO_X standard in this model year. Alternatively, manufacturers may forego this special banked credit option and instead meet an alternative phase-in requirement in 2012, 2013, and part of 2014. See Section III.B.1.b.

The proposed long-term 0.01 and 0.02 g/bhp-hr Tier 4 PM standards for >75 hp and 25–75 hp engines, respectively, combined with the fuel change and proposed new requirements to ensure robust control in the field, represent a reduction of over 95% from in-use levels expected with Tier 2/Tier 3 engines.[117] The proposed 0.30 g/bhp-hr Tier 4 NO_X standard for >75 hp engines represents a NO_X reduction of about 90% from in-use levels expected with Tier 3 engines. The basis for the proposed standard levels is presented in Section III.E.

a. Standards Timing

The timing of the Tier 4 NO_X, PM, and NMHC standards is closely tied to the proposed timing of fuel quality changes discussed in section IV, in keeping with the systems approach we are taking for this program. The earliest Tier 4 standards would take effect in model year 2008, in conjunction with the introduction of 500 ppm maximum sulfur nonroad diesel fuel in mid-2007. This fuel change serves a dual environmental purpose. First, it provides a large immediate reduction in PM emissions for the existing fleet of engines in the field. Second, its widespread availability by the end of 2007 aids engine designers in employing emission controls capable of achieving the proposed standards for model year 2008 and later engines; this is because the performance and durability of such technologies as exhaust gas recirculation (EGR) and diesel oxidation catalysts is improved by lower sulfur fuel.[118] The reduction of sulfur in nonroad diesel fuel will also provide sizeable economic benefits to machine operators as it will extend oil change intervals and reduce wear and corrosion (*see* section V).

We are not, however, proposing new 2008 standards for engines at or above 100 hp because these engines are subject to existing Tier 3 NMHC+NO_X standards (Tier 2 for engines above 750 hp) in 2006 or 2007. Setting new 2008 standards would provide only one or two years before another round of design changes would have to be made for Tier 4. Engines between 50–100 hp also have a Tier 3 NMHC+NO_X standard, but it takes effect in 2008, providing an opportunity to coordinate with Tier 4 to provide the desired pull-ahead of PM control. We believe that we can accomplish this PM pull-ahead without hampering manufacturers' Tier 3 compliance efforts by providing two Tier 4 compliance options for 50–75 hp engines. This reflects the splitting of the current 50–100 hp category of engines to match the new rated power[119] categories shown in Figures III.B–1 and 2. We are proposing to provide manufacturers with the option to skip the Tier 4 2008 PM standard (*see* Figure III-B.1) and instead to focus design efforts on introducing PM filters for these engines one year earlier, in 2012. This option would ensure that a manufacturer's Tier 3 NMHC+NO_X compliance plans are not complicated by having to meet a new Tier 4 PM standard in the same timeframe, if that were to become a concern for a manufacturer.

We are concerned that this optional approach for 50–75 hp engines might be abused by equipment manufacturers whose engine suppliers opt not to meet the PM pull-ahead standard in 2008, but who then switch engine suppliers to avoid PM filter-equipped engines in 2012. We are therefore proposing that an equipment manufacturer making a product with engines not meeting the pull-ahead standard in any of the years 2008–2011, must use engines in that product in 2012 meeting the 0.02 g/bhp-hr PM standard; that is, from the same engine manufacturer or from another engine manufacturer choosing the same compliance option. This restriction would not apply if the 2008–2011 engines at issue are being produced under the equipment manufacturer flexibility provisions discussed in section VII.B. Also, we would not prohibit an equipment manufacturer who is using non-pull-ahead engines in 2008–2011 from making use of available equipment manufacturer flexibility provisions in 2012 or later. That is, they could continue to use Tier 3 engines in 2012 that are purchased under these provisions; they would, however, still be subject to the above-described restriction on switching manufacturers. We solicit comment on whether this restriction should have a numerical basis (*e.g.*, the ''no switch'' restriction in 2012 applies to the same percentage of 50–75 hp machines produced with non-pull-ahead engines in 2008–2011) to avoid further abuse by equipment manufacturers who redefine their product models to dodge the requirement, and on other suggestions for dealing with this concern.

Note that we are not proposing the optional 2008 PM standard for engines between 75 and 100 hp, even though they, like the 50–75 hp engines, are subject to a 2008 Tier 3 standard. This is because we believe that these larger engines, proposed to be grouped into a new 75–175 hp category, would be subject to stringent new PM and NO_X standards beginning in 2012, and adding a 2008 PM component to this program for a quarter of this 75–175 hp range would complicate manufacturers' efforts to comply in 2012 for the overall category.

We view the 2008 portion of the Tier 4 program as highly important because it provides substantial PM and NO_X emissions reductions during the several years prior to 2011. Initiating Tier 4 in 2008 also fits well with the lead time, stability, cost, and technology availability considerations of the overall program.[120] Initiating the Tier 4 standards in 2008 would provide three to four years of stability after the start of Tier 2 for engines under 50 hp. As mentioned above, it also coincides with the start date of Tier 3 NO_X+NMHC standards for engines between 50 and 75 hp and so introduces no stability issues for these engines. As the Agency expects to finalize this rule in early 2004, the 2008 start date provides almost 4 years of lead time to accomplish redesign and testing. The evolutionary character of the 2008 standards, based as they are on proven technologies, and the fact that some certified engines already meet these standards as discussed in Section

[117] Note that we are grouping all standards proposed in this rule under the general designation of ''Tier 4 standards'', including those proposed to take effect in 2008. As a result, there are no ''Tier 3'' standards in the multi-tier nonroad program for engines below 50 hp or above 750 hp.

[118] ''Nonroad Diesel Emissions Standards Staff Technical Paper'', EPA420–R–01–052, October 2001.

[119] The term rated power is used in this document to mean the maximum power of an engine. *See* section VII.L for more information about how the maximum power of an engine is determined.

[120] Section 213(b) of the Clean Air Act does not specify a minimum lead time period, nor does it mandate a set minimum period of stability for the standards (differing in these respects from the comparable provision section (202(a)(3)(C)) applicable to highway engines). However, in considering the amount of lead time and stability provided, EPA takes into consideration the need to avoid disruptions in the engine and equipment manufacturing industries caused by redesign mandates that are too frequent or too soon after a final rulemaking. These are appropriate factors to consider in determining ''the lead time necessary to permit the development and application of the requisite technology'', and are part of taking cost into consideration, as required under section 213 (b).

III.E leads us to conclude that this will provide adequate lead time.

The second fuel change, to 15 ppm maximum sulfur in mid-2010, and the related engine standards that begin to phase-in in the 2011 model year, provide the large majority of the environmental benefits of the program. These standards are also timed to provide adequate lead time for manufacturers, and to phase in over time to allow for the orderly transfer of technology from the highway sector. We believe that the high-efficiency exhaust emission technologies being developed to meet our 2007 emission standards for heavy-duty highway diesel engines can be adapted to nonroad diesel applications. The engines for which we believe this adaptation from highway applications will be most straightforward are those in the over 175 hp power range, and thus under our proposal these engines would be subject to new standards requiring high-efficiency exhaust emission controls as soon as the 15 ppm sulfur diesel fuel is widely available, that is, in the 2011 model year. Engines between 75 and 175 hp would be subject to the new standards in the following model year, 2012, reflecting the greater effort involved in adapting highway technologies to these engines. Lastly, engines between 25 and 75 hp would be subject to the new PM standard in 2013, reflecting the even greater challenge of adapting PM filter technology to these engines which typically do not have highway counterparts. There are additional phase-in provisions discussed in Section III.B.1.b aimed at further drawing from the highway technology experience.

In addition to addressing technology transfer, this approach reflects the need to distribute the workload for engine and equipment redesign over three model years, as was provided for in Tier 3. Overall, this approach provides 4 to 6 years of real world experience with the new technology in the highway sector, involving millions of engines (in addition to the several additional years provided by demonstration fleets already on the road), before the new standards take effect.

b. Phase-In of NO_X and NMHC Standards

Because the Tier 4 NO_X emissions control technology, like PM control technology, is expected to be derived from technology first introduced in highway HDDEs, we believe that the implementation of the Tier 4 NO_X standard should follow the pattern we adopted for the highway program. This will help to ensure a focused, orderly development of robust high-efficiency NO_X control in the nonroad sector and will also help to ensure that manufacturers are able to take maximum advantage of the highway engine development program, with resulting cost savings. The heavy-duty highway rule allows for a gradual phase-in of the NO_X and NMHC requirements over multiple model years: 50 percent of each manufacturer's U.S.-directed production volume must meet the new standard in 2007–2009, and 100 percent must do so by 2010. We also provided flexibility for highway engine manufacturers to meet that program's environmental goals by allowing somewhat less-efficient NO_X controls on more than 50% of their production before 2010 via emissions averaging. Similarly, we are proposing to phase in the NO_X standards for nonroad diesels over 2011–2013 as indicated in Figure III.B–2, based on compliance with the Tier 4 standards for 50% of a manufacturer's U.S.-directed production in each power category at or above 75 hp in each phase-in model year.

With a NO_X phase-in, all manufacturers are able to introduce their new technologies on a limited number of engines, thereby gaining valuable experience with the technology prior to implementing it on their entire product line. In tandem with the equipment manufacturer transition program discussed in section VII.B, the phase-in ensures timely progress to the Tier 4 standards levels while providing a great degree of implementation flexibility for the industry.

We are proposing this ''percent of production phase-in'' to take maximum advantage of the highway program technology development. It adds a new dimension of implementation flexibility to the staggered ''phase-in by power category'' used in the nonroad program for Tiers 1, 2 and 3 which, though structured to facilitate technology development and transfer, is more aimed at spreading the redesign workload. Because the Tier 4 program would involve substantial challenges in addressing both technology development and redesign workload, we believe that incorporating both of these phase-in mechanisms into the proposed program is warranted, resulting in the coordinated phase-in plan shown in Figure III.B–2. Note that this results in our proposing that new NO_X requirements for 75–175 hp engines be deferred for the first year of the 2011–2013 general phase-in, in effect creating a 50–50% phase-in in 2012–2013 for this category. This then staggers the Tier 4 start years by power category as in past tiers: 2011 for engines at or above 175 hp, 2012 for 75–175 hp engines, and 2013 for 25–75 hp engines (for which no NO_X adsorber-based standard and thus no percentage phase-in is being proposed), while still providing a production-based phase-in for advanced NO_X control technologies.

We believe that the 75–175 hp category of engines and equipment may involve added workload challenges for the industry to develop and transfer technology. We note that this category, though spanning only 100 hp, represents a great diversity of applications, and comprises a disproportionate number of the total nonroad engine and machine models. Some of these engines, though having characteristics comparable to many highway engines such as turbocharging and electronic fuel control, are not directly derived from highway engine platforms and so are likely to require more development work than larger engines to transfer emission control technology from the highway sector. Furthermore, the engine and equipment manufacturers have greatly varying market profiles in this category, from focused one- or two-product offerings to very diverse product lines with a great many models. We are interested in providing useful flexibility for a wide range of companies in implementing the Tier 4 standards, while keeping a priority on bringing PM emissions control into this diverse power category as quickly as possible.

We are therefore proposing two compliance flexibility provisions just for this category. First, we propose to allow manufacturers to use NMHC+NO_X credits generated by Tier 2 engines over 50 hp (in addition to any other allowable credits) to demonstrate compliance with the Tier 4 requirement for 75–175 hp engines in 2012, 2013, and 2014 only. This would not otherwise be allowed, for reasons explained in section VII.A. These Tier 2 credits would be subject to the power rating conversion already established in our ABT program, and to the 20% credit adjustment we are proposing for use of NMHC+NO_X credits as NO_X credits. (*See* section VII.A.)

Second, we realize that some manufacturers, especially those with limited product offerings, may not have sufficient banked credits available to them to benefit from this special flexibility, and so we are also proposing an alternative flexibility provision. A manufacturer may optionally forego the Tier 2 banked credit use provision described above, and instead demonstrate compliance with a reduced phase-in requirement for NO_X and NMHC. Use of credits other than banked Tier 2 credits would still be allowed, in accordance with the other ABT program provisions. In no case could the phase-in compliance demonstration drop below 25% in each of 2012, 2013, and the first 9 months of 2014, except as allowed under the ''good faith projection deficit'' provision discussed in Section VII.D. Full compliance (100% phase-in) with the Tier 4 standards would need to be demonstrated in the last 3 months of 2014 and thereafter.

In addition, a manufacturer using this reduced phase-in option would not be allowed to generate credits from engines in this power category in 2012, 2013, and the first 9 months of 2014, except for use in averaging within this power category only (no banking or trading, or averaging with engines in other power categories). This restriction would apply throughout this period even if the reduced phase-in option is exercised during only a portion of this period. We believe that this ABT restriction is important to avoid potential abuse of the added flexibility allowance, considering that larger engine categories will be required to demonstrate substantially greater compliance levels with the 0.30 g/bhp-hr NO_X standard several years earlier than engines built under this option. The restriction should be no burden to manufacturers, as only those using the option would be subject to it, and the production of credit-generating engines would be contrary to the option's purpose.

We are proposing to phase in the Tier 4 NMHC standard with the NO_X standard, as is being done in the highway program. Engines certified to the new NO_X requirement would be expected to certify to the NMHC standard as well. The ''phase-out'' engines (the 50 percent not certified to the new Tier 4 NO_X and NMHC standards) would continue to be certified to the applicable Tier 3 NMHC+NO_X standard. As discussed in section III.E, we believe that the NMHC standard is readily achievable through the application of PM traps to meet the PM standard, which for most engines does not involve a phase-in. However, in the highway program we chose to phase in the NMHC standard with the NO_X standard for administrative reasons, to simplify the phase-in under the percent-of-production approach taken there, thus avoiding subjecting the ''phase-out'' engines to separate standards for NMHC and NMHC+NO_X. The same reasoning applies here because, as in the highway program, the previous-tier standards are combined NMHC+NO_X standards.

Because of the tremendous variety of engine sizes represented in the nonroad diesel sector, we are proposing that the 50 percent phase-in requirement be met separately in each of the three power categories for which a phase-in is proposed (75–175 hp, 175–750 hp, and >750 hp).[121] For example, a manufacturer that produces 1000 engines for the 2011 U.S. market in the 175 to 750 hp range would have to demonstrate compliance to the proposed NO_X and NMHC standards on at least 500 of these engines, regardless of how many complying engines the manufacturer produces in other hp categories. (Note, however, that we would allow averaging of emissions across these engine category cutpoints through the use of power-weighted ABT program credits, as provided for in the existing nonroad diesel engine program.) We believe that this restriction reflects the availability of emissions control technology, and is needed to avoid erosion of environmental benefits that might occur if a manufacturer with a diverse product offering were to meet the phase-in with relatively low cost smaller engines, thereby delaying compliance on larger engines with much higher lifetime emissions potential. Even so, the horsepower ranges for these power categories are fairly broad, so this restriction allows ample freedom to manufacturers to structure compliance plans in the most cost-effective manner. We could as well choose to handle this concern by weighting complying engines by horsepower, as we do in the ABT program, but we believe that creating a simple phase-in structure based simply on counting engines, as we did in the highway HDDE rule, avoids unnecessary complexity and functional overlap with ABT.

c. Rationale for Restructured Horsepower Categories

We are proposing to regroup the power categories in the proposed Tier 4 program compared to the previous tiers of standards.[122] We are doing so because this will more closely match the degree of challenge involved in transferring advanced emissions control technology from highway engines to nonroad engines. For a variety of reasons, highway engines have in the past been equipped with new emission control technologies some years before nonroad engines. As a result, the nonroad engine platforms that are directly derived from highway engine designs in turn become the lead application point for the migration of emission control technologies into the nonroad sector. Smaller and larger nonroad engines, as well as similar-sized engines that cannot directly use a highway base engine (such as farm tractor engines that are structurally part of the tractor chassis), may then employ these technologies after additional lead time for needed adaptation. This progression has been reflected in EPA standards-setting activity to date, especially in implementation schedules, in which the earliest standards are applied to engines in the most ''highway-like'' power categories.

Although there is not an abrupt power cutpoint above and below which the highway-derived nonroad engine families do and do not exist, we believe that 75 hp is a more appropriate cutpoint for this purpose than either of the closest previously adopted power category cutpoints of 50 or 100 hp. These two cutpoints were first adopted in a 1994 final rule that chose them in order to establish categories for a staggered implementation schedule designed to spread out development costs (59 FR 31306, June 17, 1994). Nonroad diesels produced today with rated power above 75 hp (up to several hundred hp) are mostly variants of nonroad engine platforms with four or more cylinders and per-cylinder displacements of one liter or more. These in turn are derived from or are similar to heavy-duty highway engine platforms. Even where nonroad engine models above 75 hp are not so directly derived from highway models, they typically share many common characteristics such as displacements of one liter per cylinder or more, direct injection fueling, turbocharging, and, increasingly, electronic fuel injection. These common features provide key building blocks in transferring high-efficiency exhaust emission control technology from highway to similar nonroad diesel engines. We have discussed this matter with relevant engine manufacturers, and we are confident based on these discussions that 75 hp represents an industry consensus on the appropriate cutpoint for this purpose. We invite comment on the 75 hp cutpoint.

We are therefore proposing to regroup power ratings using the 75 hp cutpoint. Some have expressed that this may somewhat complicate the transition from tier to tier and efforts to harmonize with the European Union's nonroad diesel program (which currently uses

[121] Note proposed exceptions to the 50 percent requirements during the phase-in model years discussed in sections VII.D and VII.E. These deal with differences between a manufacturer's actual and projected production levels, and with incentives for early or very low emission engine introductions.

[122] The Tier 1 / 2 / 3 programs make use of 9 categories divided by horsepower: <11, 11–25, 25–50, 50–100, 100–175, 175–300, 300–600, 600–750, and >750 hp.

power cutpoints corresponding to 50 and 100 hp). However, we believe that it provides substantial long-term benefits for the environment (for example, by linking NO_X standard-setting to an engine technology-based 75 hp cutpoint). We will continue working with key entities to advance harmonization as this rule is developed.

We are also proposing to consolidate some power categories that were created in the past to allow for variations in standards levels and timing appropriate for Tiers 1, 2 and 3, and that remain in effect for those tiers, but which under this proposal are no longer distinct from each other with respect to standards levels and timing. These consolidations are: (1) The less than 11 hp and 11–25 hp categories into a single category of less than 25 hp, (2) the 75–100 hp portion of the 50–100 hp category and the 100–175 hp category into a single category of 75–175 hp, and (3) the 175–300 hp, 300–600 hp, and 600–750 hp categories into a single category of 175–750 hp. The result is the 5 power bands shown in Figures III.B–1 and 2 instead of the former 9. This will also help to facilitate use of equipment manufacturer transition flexibility allowances which can be applied only within each power band, as discussed in section VII.B. We ask for comment on this regrouping, especially with regard to the appropriate power cutpoint for the engine families that are similar to highway engine families. Again, most useful in this regard would be information showing how highway and nonroad engines in this range do or do not share common design bases.

d. PM Standards for Smaller Engines

i. <25 hp

We believe that standards based on the use of PM filters should not be proposed at this time for the very small diesel engines below 25 hp. Although this technology could be adapted to these engines, the cost of doing so with known technology could be unacceptably high, relative to the cost of producing the engines themselves. Based on past experience, we expect that advancements in reducing these costs will occur over time. We plan to reassess the appropriate long-term standards in a technology review as discussed in section III.G. For the nearer-term, we believe that other proven PM-reducing technologies such as diesel oxidation catalysts and engine optimization can be applied to engines under 25 hp for very cost-efficient PM control, as discussed in sections III.E and V.A. When implemented, the PM standard proposed in Figure III.B–1 for these engines, along with the proposed transient test cycle, will yield an in-use PM reduction of over 50% for these engines, and large reductions in toxic hydrocarbons as well. Achieving these emission reductions is very important, considering the fact that many of these smaller engines operate in populated areas and in equipment without closed cabs— in mowers, portable electric power generators, small skid steer loaders, and the like. We invite comment on this proposed approach to controlling harmful emissions from very small nonroad diesel engines.

It is our assessment that achieving low PM emission levels is especially challenging for one subclass of small engines: the air-cooled, direct injection engines under 11 hp that are startable by hand, such as with a crank or recoil starter. These typically one-cylinder engines find utility in applications such as plate compactors, where compactness and simplicity are needed, but where the ruggedness typical of a diesel engine is also essential. There are a number of considerations in the design, manufacture, and marketing of these engines that combine to make them difficult to optimize for low emissions. These include the air-cooled engine's need for relatively loose design fit tolerances to accommodate thermal expansion variability (which can lead to increased soluble organic PM), small cylinder displacement and bore sizes that limit use of some combustion chamber design strategies and increase the propensity for PM-producing fuel impingement on cylinder walls, the difficulty in obtaining components for small engines with machining tolerances tight enough to yield consistent emissions performance, and cost reduction pressures caused by competition from cheaper gasoline engines in some of the same applications.

As a result, we are proposing an alternative compliance option that allows manufacturers of these engines to delay Tier 4 compliance until 2010, and in that year to certify them to a PM standard of 0.45 g/hp-hr, rather than to the 0.30 g/hp-hr PM standard applicable to the other engines in this power category beginning in 2008. Engines certified under this alternative compliance requirement would not be allowed to generate credits as part of the ABT program, although credit use by these engines would still be allowed. We believe that this ABT restriction is important to avoid potential abuse of this option, and is a reasonable means of dealing with the concern as it would apply only to those air-cooled, hand-startable, direct injection engines under 11 hp that are certified under this special compliance option, and the production of credit-generating engines would be contrary to the option's purpose. Furthermore, because the proposed 2010 Tier 4 implementation year for these engines is the same year that 15 ppm sulfur nonroad diesel fuel would become available, we are also proposing that certification testing and any subsequent compliance testing on engines certified under this option may be conducted using the 7–15 ppm sulfur test fuel discussed in section VII.H. Although this is one year earlier than would be otherwise allowable, we believe it would have a minimal impact on the proposed program's environmental benefit considering the extremely small contribution these engines make to emissions inventories, and the fact that these engines would generally operate in the field on higher sulfur fuels for at most a few months.

ii. 25–75 hp

We believe that the proposed 0.22 g/bhp-hr PM standard for 25–75 hp engines in 2008 is warranted because the Tier 2 PM standards that take effect in 2004 for these engines, 0.45 and 0.30 g/bhp-hr for 25–50 and 50–75 hp engines, respectively, do not represent the maximum achievable reduction using technology which will be available by 2008. However, as discussed in section III.B.1.a, filter-based technology for these engines is not expected to be available on a widespread basis until the 2013 model year. The proposed 2008 PM standard for these engines should maximize reduction of PM emissions based on technology available in that year. We believe that the 2008 standards are feasible for these engines, based on the same engine or oxidation catalyst technologies feasible for engines under 25 hp in 2008, following the proposed introduction of nonroad diesel fuel with sulfur levels reduced below 500 ppm. We expect in-use PM reductions for these engines of over 50%, and large reductions in toxic hydrocarbons as well over the five model years this standard would be in effect (2008–2012). These engines will constitute a large portion of the in-use population of nonroad diesel engines for many years after 2008.

We request comment on our proposal to implement Tier 4 PM standards for 25–75 hp engines in the two phases just noted: a non-PM filter based standard in 2008 and a filter-based standard in 2013. In addition, we request comment on whether it would be better not to set a Tier 4 PM standard in 2008 so that engine designers could instead focus their efforts on meeting a PM-filter based standard for these engines earlier, say in 2012. (It should be noted that the proposed rule would provide this as an option for a subgroup of these engines (50–75 hp). *See* Figure III.B–1 note b.) We would assume that under this approach the proposed new NO_X+NMHC standard for 25–50 hp engines in this category would also start in 2012, to avoid requiring two design changes in two years. Any comments in support of this approach should, if possible, include information to support a conclusion that the earlier start date for a PM filter-based standard would be technologically feasible.

We believe that the proposed 2008 PM standards for engines under 75 hp can be met either through engine optimization, by the use of diesel oxidation catalysts, or by some combination thereof, as discussed in section III.E. For engines that comply through the use of oxidation catalysts, NMHC emissions are expected to be very low because properly designed oxidation catalysts are effective at oxidizing gaseous hydrocarbons as well as the soluble organic fraction of diesel exhaust PM. Engines complying with the proposed 2008 PM standard without the use of oxidation catalysts would, on the other hand, be expected to emit NMHC at about the same levels as Tier 2 engines. Recognizing that NMHC emissions from diesel engines can include a number of toxic compounds, and that there are many of these small diesel engines operating in populated areas, we are interested in comment on the appropriateness of setting a more stringent NMHC standard for these engines in 2008 to better control these emissions. We expect that doing so would likely result in more widespread use of oxidation catalysts (rather than engine optimization) for these engines. We would not, however, expect this to lead to a more stringent PM standard than the one we are proposing, based on the feasibility discussion in section III.E.

e. Engines Above 750 hp

For engines above 750 hp, additional lead time to fully implement Tier 4 is warranted due to the relatively long product design cycles typical of these high-cost, low-sales volume engines and machines. The long product design cycle issue is the primary reason we did not set Tier 3 standards for these engines in the 1998 rule and are not proposing to do so now. Instead, we are proposing that these engines move from the Tier 2 standards, which take effect in 2006, to Tier 4 standards beginning in 2011, five years later. Moreover, we are proposing that the Tier 4 PM standard be phased in for these engines on the same 50–50–50–100% schedule as the NO_X and NMHC phase-in schedule, rather than all at once in 2011 as for engines between 175 and 750 hp. (*See* Figure III.B–1.) This would provide engine manufacturers with up to 8 years of design stability to address concerns associated with product design cycles and low sales volumes typical of this category. The engine manufacturer ABT program adds additional flexibility. Even longer stability periods could exist for equipment manufacturers using these engines because they have their own transition flexibility provisions available on top of the engine standard phase-in. This is especially significant because many of these large machines are built by manufacturers who build their own engines, or who work closely with their engine suppliers, and can thus create a long-term product plan making coordinated use of engine and equipment flexibility provisions.

We think that, taken together, these provisions appropriately balance the need for expeditious emission reductions with issues relating to lead time, technology development, and cost for these engines and machines. Even so, some engine and equipment manufacturers have expressed concerns to us that, though not challenging the Tier 4 program endpoint (high-efficiency PM and NO_X exhaust emission controls), in their estimation our proposed program implementation provisions do not adequately address their timing concerns. In particular, they have expressed a view that they need until 2012 (one additional year) before they could begin to phase in Tier 4 standards for this category. They have also expressed the view that mobile machinery such as mine haul trucks and dozers (as differentiated from equipment such as nonroad diesel generators that also use engines in this hp range) present unique challenges that could require more time to resolve than would be afforded by the proposed 2014 phase-in completion date.

Although we believe that the implementation schedule and flexibility provisions we are proposing will enable the manufacturers to meet these challenges, we acknowledge the manufacturers' concerns and ask for comment on this issue. Specifically, we request comment on whether this category, or some subset of it defined by hp or application, should have a later phase-in start date, a later phase-in end date, adjusted standards, additional equipment manufacturer flexibility provisions, or some combination of these. Technical information backing the commenter's view would be most helpful in this regard.

As with the NO_X/NMHC phase-in for all engines at or above 75 hp, we are proposing that the PM phase-in for engines above 750 hp would have to be met on the same engines as the Tier 4 NO_X and NMHC standards during the phase-in years. That is, engines certified to the Tier 4 NO_X and NMHC requirements would be expected to certify to the Tier 4 PM standard as well.

f. CO Standards

We are proposing minor changes in CO standards for some engines solely for the purpose of helping to consolidate power categories. These amount to a change for engines under 11 hp from 6.0 to 4.9 g/bhp-hr in 2008 to match the existing Tier 2 CO standard for 11–25 hp engines, and a change for engines at or above 25 hp but below 50 hp from 4.1 to 3.7 g/bhp-hr to match the existing Tier 3 CO standard for 50–75 hp engines, also in 2008. These minor proposed changes are not expected to add a notable compliance burden. Nevertheless, we expect that the use of high-efficiency exhaust emission controls will yield a substantial reduction in CO emissions, as discussed in Chapter 4 of the draft RIA.

These minor adjustments to the CO standard are based solely on our desire to simplify the administrative process for the engine manufacturers which arises from the reduction in the number of the engine power categories we have proposed for Tier 4. We are not exercising our authority to revise the CO standard for nonroad diesel engines for the purpose of improving air quality at this time, and therefore the minor adjustments we have proposed today, though feasible, are not based on a detailed evaluation of the capabilities of advanced exhaust aftertreatment technology to reduce CO levels.

g. Exclusion of Marine Engines

These proposed emission standards would apply to engines in the same applications covered by EPA's existing nonroad diesel engine standards, at 40 CFR part 89, except that they would not apply to marine diesel engines. Marine diesel engines below 50 hp were included in our 1998 rule that set nonroad diesel emission standards (63 FR 56968, October 23, 1998). In that rule, we expected that the engine modifications needed to achieve those standards (*e.g.*, in-cylinder controls) for marine engines would not need to be different from those for land-based engines of this size.

The standards for diesel engines below 50 hp being proposed in this action are likely to require PM filters or diesel oxidation catalysts on many or all engines, and transferring this technology to the marine diesel engines of any size raises unique issues. For example, many marine diesel engines have water-jacketed exhaust which may result in different exhaust temperatures and which could affect aftertreatment efficiency. The modified marine engine designs would also have to meet Coast Guard requirements. These and other conditions may require separate design efforts for marine diesel engines. Therefore, we believe it is more appropriate to consider more stringent standards for marine diesel engines below 50 hp in a future action. It should be noted, however, that the existing Tier 2 standards will continue to apply to marine diesel engines under 50 hp until that future action is completed.

2. Crankcase Emissions Control

Crankcase emissions are the pollutants that are emitted in the gases that are vented from an engine's crankcase. These gases are also referred to as ''blowby gases'' because they result from engine exhaust from the combustion chamber ''blowing by'' the piston rings into the crankcase. These gases are often vented to prevent high pressures from occurring in the crankcase. Our existing emission standards require control of crankcase emissions from all nonroad diesel engines except turbocharged engines. The most common way to eliminate crankcase emissions has been to vent the blowby gases into the engine air intake system, so that the gases can be recombusted. Following the precedent we set for heavy-duty highway diesel engines in an earlier rulemaking, we made the exception for turbocharged nonroad diesel engines because of concerns about fouling that could occur by routing the diesel particulates (including engine oil) into the turbocharger and aftercooler. Our concerns are now alleviated by newly developed closed crankcase filtration systems, specifically designed for turbocharged diesel engines. These new systems are already required in parts of Europe for new highway diesel engines under the EURO III emission standards, and are expected to be used in meeting new U.S. EPA crankcase emission control standards for heavy-duty highway diesel engines beginning in 2007 (*see* section III.C.1.c of the preamble to the 2007 heavy-duty highway final rule).

We are therefore proposing to eliminate the exception for turbocharged nonroad diesel engines starting in the same model year that Tier 4 exhaust emission standards first apply in each power category. This is 2008 for engines below 75 hp, except for 50–75 hp engines for which a manufacturer opts to skip the 2008 PM standard. The crankcase requirement applies to ''phase-in'' engines above 750 hp under the 50% phase-in requirement for 2011–2013, but not to the ''phase-out'' engines in that power category during those years. This is an environmentally significant proposal since many nonroad machine models use turbocharged engines, and a single engine can emit over 100 pounds of NO_X, NMHC, and PM from the crankcase over the lifetime of the engine. We also note that the cost of control is small (*see* section V).

Our existing regulatory requirement for controlling crankcase emissions from naturally-aspirated nonroad engines allows manufacturers to route the crankcase gases into the exhaust stream instead of the engine air intake system, provided they keep the combined total of the crankcase emissions and the exhaust emissions below the applicable exhaust emission standards. We are proposing to extend this allowance to the turbocharged engines as well. We are also proposing to give manufacturers the option to measure crankcase emissions instead of completely eliminating them, and adding the measured emissions to exhaust emissions in assessing compliance with exhaust emissions standards. This allowance was adopted for highway HDDEs in 2001 (*see* section VI.A.3 of the preamble to the 2007 heavy-duty highway final rule). As in the highway program, manufacturers choosing to use this allowance rather than to seal the crankcase would need to modify their exhaust deterioration factors or to develop separate deterioration factors to account for increases in crankcase emissions as the engine ages. Manufacturers would also be responsible for ensuring that crankcase emissions would be readily measurable in use.

C. What Test Procedure Changes Are Being Proposed?

We are proposing a number of changes to the certification test procedures by which compliance with emission standards is determined. Two of these are particularly significant: The addition of a supplemental transient emissions test and the addition of a cold start testing component to the proposed transient emissions test. These are discussed briefly in this section, and in more detail in section VII.F. Other proposed changes are also discussed in section VII.F and deal with:

- Adoption of an improved smoke testing procedure, with associated standards levels and exemptions.
- Addition of a steady-state test cycle for transportation refrigeration units.
- Test procedure changes intended to improve testing precision, especially with regards to sampling methods.
- A clarification to existing EPA defeat device regulations.

1. Supplemental Transient Test

In the 1998 final rule that set new emission standards for nonroad diesel engines, we expressed a concern that the steady-state test cycles used to demonstrate compliance with emission standards did not adequately reflect transient operation, and, because most nonroad engines are used in applications that are largely transient in nature, would therefore not yield adequate control in use (63 FR 56984, October 23, 1998). Although we were not prepared to adopt a transient test at that time, we announced our intention in that final rule to move forward with the development of such a test. This development has progressed steadily since that time, and has resulted in the creation of a Nonroad Transient Composite (NRTC) test cycle, which we are now proposing to adopt in our nonroad diesel program, to supplement the existing steady-state tests. We expect that this proposed requirement will significantly reduce real world emissions from nonroad diesel equipment. Instead of sampling engine operation at the few isolated operating points of steady-state emission tests, proper transient testing can capture emissions from the broad range of engine speed and load combinations that the engine may attain in use, as well as emissions resulting from the change in speed or load itself, such as those induced by turbocharger lag.

The proposed NRTC cycle will capture transient emissions over much of the typical nonroad engine operating range, and thus help ensure effective control of all regulated pollutants. In keeping with our goal to maximize the harmonization of emissions control programs as much as possible, we have developed this cycle in collaboration with nonroad engine manufacturers and regulatory bodies in the United States, Europe, and Japan over the last several years.[123] Further, the NRTC cycle has been introduced as a work item for

[123] Letter from Jed Mandel of the Engine Manufacturers Association to Chet France of U.S. EPA, Office of Transportation and Air Quality, Docket A–2001–28.

possible adoption as a potential global technical regulation under the 1998 Agreement for Working Party 29 at the United Nations.[124]

The Agency is proposing that emission standards be met on both the current steady-state duty cycles and the new transient duty cycles. The transient testing would begin in the model year that the trap-based Tier 4 PM standards and/or adsorber-based Tier 4 NO_X standards first apply. This would be 2011 for engines at or above 175 hp, 2012 for 75–175 hp engines (2012 for 50–75 hp engines made by a manufacturer choosing the optional approach described in footnote b of Figure III.B–1), and 2013 for engines under 75 hp. *See also* Table VII.F.–1. In addition, any engines for which a manufacturer claims credit under the incentive program for early-introduction engines (*see* section VII.E) would have to be certified to that program's standards under the NRTC cycle and, in turn, the 2011 or later model year engines that use these engine count-based credits would not need to demonstrate compliance under the NRTC cycle.

Although we intend that transient emissions control be an integral part of Tier 4 design considerations, we do not believe it appropriate to mandate compliance with the transient test for the engines under 75 hp subject to proposed PM standards in 2008. We recognize that transient emissions testing, though routine in highway engine programs, involves a fair amount of new laboratory equipment and expertise in the nonroad engine certification process. As with the transfer of advanced emission control technology itself, we believe that the transient test requirement should be implemented first for larger engines more likely to be made by engine manufacturers who also have highway engine markets. We do not believe that the smaller engines should be the lead power categories in implementing the new transient test, especially because many manufacturers of these engines do not make highway engines and are not as experienced or well-equipped as their large-engine counterparts for conducting transient cycle testing.

Engines below 25 hp involve an additional consideration for timing of the transient test requirement because we are not proposing PM-filter based standards for them. We propose that testing on the NRTC cycle not be required for these engines until the 2013 model year, the last year in which engines in higher power categories are required to use this test. We are concerned that manufacturers not view this proposed deferral of the transient test requirement as a structured second level of required control for these engines. To address this concern and because we wish to encourage the demonstration of transient emission control as early as possible, we are proposing to allow manufacturers to optionally certify engines below 25 hp under the NRTC cycle beginning in the 2008 model year, and to extend this option to 25–75 hp engines subject to engines meeting the transitional PM standard in 2008. (*See also* the discussion in section VII.F.1 on this issue.) We request comment on this proposed approach and on whether it would be better to deal with this concern by requiring compliance under the transient test when the Tier 4 standards begin in 2008.

In applying the NRTC test requirement coincident with the start of PM filter-based standards, we do not mean to imply that control of PM from filter-equipped engines is the only or even the primary concern being addressed by transient testing. In fact, we believe that advanced NO_X emission controls may be more sensitive to transient operation than PM filters. It is, however, our intent that the control of emissions during transient operation be an integral part of Tier 4 engine design considerations, and we therefore have proposed that transient testing be applied with the PM filter-based Tier 4 PM standards, because these standards precede or accompany the earliest Tier 4 NO_X or NMHC standards in every power category. Even so, we request comment on whether the ''phase-out'' engines above 75 hp (those engines for which compliance with the Tier 4 NO_X standard is not required during the phase-in period) should be exempted from the requirement to meet the applicable NMHC+NO_X standard using the transient test. Although our interest in ensuring transient emissions control as quickly as possible in the Tier 4 program, and in avoiding test program complexity, would argue against this approach, we are also interested in not diverting engine designers from the challenging task of redesigning engines to meet the proposed 0.30 g/bhp-hr Tier 4 NO_X standard before and during the phase-in years by having to deal with transient control under an NMHC+NO_X standard that is being phased out.

We are in fact not proposing to apply the transient test to phase-out engines above 750 hp that are carried over from pre-2011 Tier 2 engine designs. Unlike phase-out engines at or below 750 hp, these engines are not subject to a Tier 4 PM standard in 2011. They would thus be Tier 2 engine designs and we do not believe that subjecting them to transient testing would be appropriate. On the other hand, engines in any power category certified to an average NO_X standard under the ''split family'' provision described in section VII.A would all be subject to the transient test requirement, as they would clearly have to be substantially redesigned to achieve Tier 4 compliance, regardless of whether or not they use high-efficiency exhaust emission controls.

The Agency is proposing that engine manufacturers may certify constant-speed engines using EPA's Constant Speed Variable Load (CSVL) transient duty cycle[125] as an alternative to testing these engines under the NRTC provisions. The CSVL transient cycle more closely matches the speed and load operating characteristics of many constant-speed nonroad diesel applications than EPA's proposed NRTC cycle.[126] However, the manufacturer would be obligated to ensure that such engines would be used only in constant-speed applications. A more detailed discussion of the proposed NRTC and CSVL supplemental transient test cycles and associated provisions is contained in section VII.F of this preamble and in chapter 4 of the Draft RIA.

2. Cold Start Testing

In the field, the typical nonroad diesel machine will be started and will warm to a point of heat-stable operation at least once a workday. Such ''cold start'' conditions may also occur at other times over the course of the workday, after a lunch break for example. During these periods of cold start operation, the engine may be emitting at a higher rate than when the engine is running efficiently at its stabilized operating temperature. This may be especially the case for emission control designs employing catalytic devices in the exhaust system, which require heating to a ''light-off'' temperature to begin working. EPA's highway engine and vehicle programs, which have resulted in increasingly widespread use of such catalytic devices, have recognized and dealt with this concern for several years,

[124] Informal Document No. 2, ISO—45th GRPE, ''Proposal for a Charter for the Working Group on a New Test Protocol for Exhaust Emissions from Nonroad Mobile Machinery,'' 13–17 January 2003, Docket A–2001–28.

[125] Memoranda from Kent Helmer to Cleophas Jackson, ''Speed and Load Operating Schedule for the Constant Speed Variable Load (CSVL) transient test cycle'' and ''CSVL Cycle Construction''; and Southwest Research Institute—Final Report, all in Docket A–2001–28.

[126] Memorandum from Kent Helmer to Cleophas Jackson, ''Brake-specific Emissions Impact of Nonroad Diesel Engine Testing Over the NRTC, AWQ, and AW1 duty cycles'', Docket A–2001–28.

typically by repeating transient tests in both the ''cold'' and ''hot'' conditions, and weighting emission results in some fashion to create a combined result for evaluation against emission standards.

We believe that our proposed move to supplemental transient testing, combined with our proposed Tier 4 standards that will bring about the use of catalytic devices in nonroad diesel engines, makes it imperative that we also propose to include such a cold start test as part of the transient test procedure requirement. We propose to weight the cold start emission test results as one-tenth of the total with hot-start emissions accounting for the other nine-tenths. The one-tenth weighting factor is derived from a review of the present nonroad equipment population. For more detailed information on this proposal, refer to section VII.F of this preamble and chapter 4 of the Draft RIA. EPA requests comment on this approach to ensuring control of cold start emissions.

D. What Is Being Done To Help Ensure Robust Control in Use?

EPA's goal is to ensure real-world emissions control over the broad range of in-use operation that can occur, rather than just controlling emissions over prescribed test cycles executed under restricted laboratory conditions. An important tool for achieving this in-use emissions control is the setting of Not-To-Exceed (NTE) emission standards, which, in this notice, the Agency is proposing to adopt for new nonroad engines. EPA is also considering two additional means of in-use emissions control that will be proposed in separate notices. These are (1) a manufacturer-run in-use emissions test program and (2) on-board diagnostics (OBD) requirements for new nonroad diesel engines. When implemented, all three of these will help assure that in-use emissions control is achieved.

1. Not-to-Exceed Requirements

EPA proposes to adopt not-to-exceed (NTE) emission standards for all new nonroad diesel engines subject to the Tier 4 emissions standards beginning in 2011 proposed in section III. B. of this proposal. EPA already has similar NTE standards set for highway heavy-duty diesel engines, compression ignition marine engines, and nonroad spark-ignition engines.

To help ensure that nonroad diesel emissions are controlled over the wide range of speed and load combinations commonly experienced in-use, EPA is proposing to apply NTE limits and related test procedures. The NTE approach establishes an area (the ''NTE zone'') under the torque curve of an engine where emissions must not exceed a specified value for any of the regulated pollutants. The NTE standard would apply under any conditions that could reasonably be expected to be seen by that engine in normal vehicle operation and use, within certain broad ranges of real ambient conditions. The NTE requirements would help to ensure emission benefits over the full range of in-use operating conditions. EPA believes that basing the emissions standards on a set of distinct steady state and transient cycles and using the NTE zone to help ensure in-use control creates a comprehensive program. In addition, the NTE requirements would also be an effective element of an in-use testing program. The test procedure is very flexible so it can represent most in-use operation and ambient conditions. Therefore, the NTE approach takes all of the benefits of a numerical standard and test procedure and expands it to cover a broad range of conditions. Also, with the NTE approach, in-use testing and compliance become much easier since emissions may be sampled during normal vehicle use. A standard that relies on laboratory testing over a very specific driving schedule makes it harder to perform in-use testing, especially for engines, since the engines would have to be removed from the vehicle. Testing during normal vehicle use, using an objective numerical standard, makes enforcement easier and provides more certainty of what is occurring in use versus a fixed laboratory procedure.

In today's notice, we are proposing an NTE standard which is based on the approach taken for the 2007 highway heavy-duty diesel engines. In addition, we are requesting comment on an alternative NTE standard approach which, while different from the highway NTE standard approach, is designed to achieve the same environmental objectives. Both of these approaches are described below.

a. NTE Standards We Are Proposing

The Agency proposes to adopt for new Tier 4 non-road diesel engines similar NTE specifications as those finalized as part of the heavy-duty highway diesel engine rulemaking (*See* 66 FR 5001, January 18, 2001). These specifications for the highway diesel engines are contained in 40 CFR part 86.007–11 and 40 CFR part 86.1370–2007.

Our NTE proposal for nonroad contains the same basic provisions as the highway NTE. The proposed nonroad NTE standard establishes an area (the ''NTE control area'') under the torque curve of an engine where emissions must not exceed a specified value for any of the regulated pollutants.[127] This NTE control area is defined in the same manner as the highway NTE control areas, and is therefore a subset of the engine's possible speed and load operating range. The NTE standard would apply under any engine operating conditions that could reasonably be expected to be seen by that engine in normal vehicle/equipment operation and use which occurs within the NTE control zone and which also occurs during the wide range of real ambient conditions specified for the NTE. The NTE standard applies to emissions sampled during a time duration as small as 30 seconds. The NTE standard requirements for nonroad diesel engines are summarized below and specified in the proposed regulations at 40 CFR 1309.101 and 40 CFR 1039.515. These requirements would take effect as early as 2011, as shown in shown in Table III.D–1. The NTE standard would apply to engines at the time of certification as well as in use throughout the useful life of the engine.

TABLE III.D–1.—NTE STANDARD IMPLEMENTATION SCHEDULE

Power category	NTE Implementation model year [a]
<25 hp	2013
25–75 hp	[b] 2013

[127] Torque is a measure of rotational force. The torque curve for an engine is determined by an engine ''mapping'' procedure specified in the Code of Federal Regulations. The intent of the mapping procedure is to determine the maximum available torque at all engine speeds. The torque curve is merely a graphical representation of the maximum torque across all engine speeds.

TABLE III.D–1.—NTE STANDARD IMPLEMENTATION SCHEDULE—Continued

Power category	NTE Implementation model year [a]
75–175 hp	2012
175–750 hp	2011
>750 hp	[c] 2011

Notes:
[a] The NTE applies for each power category once Tier 4 standards were implemented, such that all engines in a given power category are required to meet NTE standards.
[b] The NTE standard would apply in 2012 for any engines in the 50–75 hp range who choose not to comply with the proposed 2008 transitional PM standard.
[c] The NTE standard only applies to the 50 percent of the engines in the >750 hp category which are complying with the proposed Tier 4 standard. Beginning in 2014 the NTE standard would apply to all nonroad engines >750 hp when the remaining 50 percent of the engines must comply with the Tier 4 standard.

The NTE test procedure can be run in nonroad equipment during field operation or in an emissions testing laboratory using an appropriate dynamometer. The test itself does not involve a specific operating cycle of any specific length, rather it involves nonroad equipment operation of any type which could reasonably be expected to occur in normal nonroad equipment operation that could occur within the bounds of the NTE control area. The nonroad equipment (or engine) is operated under conditions that may reasonably be expected to be encountered in normal vehicle operation and use, including operation under steady-state or transient conditions and under varying ambient conditions. Emissions are averaged over a minimum time of thirty seconds and then compared to the applicable emission standard. The NTE standard applies over a wide range of ambient conditions, including up to an altitude of 5,500 feet above-sea level at ambient temperatures as high as 86 deg. F, and at sea-level up to ambient temperatures as high as 100 deg. F. The specific temperature and altitude conditions under which the NTE applies, as well as the proposed methodology for correcting emissions results for temperature and/or humidity are specified in the proposed regulations.

In addition, as with the 2007 highway NTE standard, we are proposing a transition period during which a manufacturer could apply for an NTE deficiency for a nonroad diesel engine family. The NTE deficiency provisions would allow the Administrator to accept a nonroad diesel engine as compliant with the NTE standards even though some specific requirements are not fully met. We are proposing these NTE deficiency provisions because we believe that, despite the best efforts of manufacturers, for the first few model years it is possible some manufacturers may have technical problems that are limited in nature but can not be remedied in time to meet production schedules. We are not limiting the number of NTE deficiencies a manufacturer can apply for during the first 3 model years for which the NTE applies. For the fourth through the seventh model year after which the NTE standards are implemented, a manufacturer could apply for no more than three NTE deficiencies per engine family. No deficiency may be applied for or granted after the seventh model year. The NTE deficiency provision will only be considered for failures to meet the NTE requirements. EPA will not consider an application for a deficiency for failure to meet the FTP or supplemental transient standards.

The NTE standards we are proposing are a function of FTP emission standards contained in this proposal and described in section III.B. As with the NTE standards we have established for the 2007 highway rule, we are proposing an NTE standard which is determined as a multiple of the engine families underlying FTP emission standard. In addition, as with the 2007 highway standard, the multiple is either 1.25 or 1.5, depending on the value of the FTP standard (or the engine families FEL). These multipliers are based on EPA's assessment of the technological feasibility of the NTE standard, and our assessment that as the underlying FTP standard becomes more stringent, the NTE multiplier should increase (from 1.25 to 1.5). The proposed standard or FEL thresholds for the 1.25x multiplier and the 1.5x multiplier are specified for each regulated emission in Table III.D–2.

TABLE III.D–2.—THRESHOLDS FOR APPLYING NTE STANDARD OF 1.25XFTP STANDARD VS. 1.5X FTP STANDARD

Emission	Apply 1.25xNTE when . . .	Apply 1.5xNTE when . . .
NO_X	NO_X std or FEL ≥1.5 g/bhp-hr	NO_X std or FEL <1.5 g/bhp-hr
NMHC	NO_X std or FEL ≥1.5 g/bhp-hr	NO_X std or FEL <1.5 g/bhp-hr
NO_X+NMHC	NMHC+NO_X std or FEL ≥1.6 g/bhp-hr	NMHC+NO_X std or FEL <1.6 g/bhp-hr
>PM	PM std or FEL ≥0.05 g/bhp-hr	PM std or FEL <0.05 g/bhp-hr
CO	All stds or FELs	No stds or FELs

For example, beginning in 2011, the proposed NTE standard for engines meeting a FTP PM standard of 0.01 g/bhp-hr and a FTP NO_X standard of 0.30 g/bhp-hr would be 0.02 g/bhp-hr PM and 0.45 g/bhp-hr NO_X.

In addition, the nonroad NTE proposal specifies a number of additional engine operating conditions which are not subject to the NTE standard. Specifically: The NTE does not apply during engine start-up conditions; the NTE does not apply during very cold engine intake conditions defined in the proposed regulations for EGR equipped engines during which the engine may require an engine protection strategy; and, finally, for engines equipped with an exhaust emission control device (such as a CDPF or a NO_X adsorber), the NTE does not apply during warm-up conditions for the exhaust emission control device, specifically the NTE does not apply with the exhaust gas temperature on the outlet side of the exhaust emission control device is less than 250 degrees Celsius.

b. Comment Request on an Alternative NTE Approach

In addition the Agency requests comment on the following set of NTE specifications as an alternative to those NTE provisions proposed. This alternative NTE would use the same numeric standard values as under the proposed NTE standards discussed in section III.D.1a, however, the test procedure itself is quite different, as described below. The Agency believes that these alternative specifications and the range of operation covered by the standard would provide for similar, if not more robust nonroad engine compliance compared to the application of the proposed NTE specifications to nonroad engines. These alternative provisions have been developed to emphasize compliance over all engine operation, including engine operation that would not be covered under the proposed NTE approach. In addition these specifications were developed specifically to simplify on-vehicle testing for NTE compliance. The NTE control area would include all engine operation. The averaging intervals over which NTE standards must be met are different than the 30-second minimum set in the proposal. They are variable in time but are constant as a function of work. Emissions would be measured over a constant averaging work interval, determined as ten percent (10%) of the total work performed by the engine over a specified period of time (*e.g.*, a minimum of six hours of operation). This 10% window of work ''moves'' through data at one percent (1%) increments so as to always return about ninety (90) individual data points for direct comparison to the NTE standards.

Comments should address the potential exclusive use of these alternative provisions for nonroad diesel engine NTE compliance. For more detailed information on these alternative NTE provisions, refer to Preamble section VIIG ''Not-to-Exceed Requirements'' and chapter 4 of the draft RIA of this proposal.

2. Plans for a Future In-Use Testing and Onboard Diagnostics

In addition to the proposals in this notice, EPA is currently reviewing several related regulatory provisions concerning control of emissions from nonroad diesel engines. They are not included in this proposal, as EPA believes these aspects of an effective emission control program would benefit from further evaluation and development prior to their proposal. EPA intends to explore these provisions further in the coming months and publish a separate notice of proposed rulemaking dealing with these issues. In particular, there are two issues which will be discussed: (1) A manufacturer-run in-use emissions testing program; and (2) OBD requirements for nonroad diesel engines. The Agency believes that it is appropriate to proceed with the current rulemaking, expecting that these two issues will be proposed in the near future. EPA expects these programs would be adopted in advance of the effective date of the engine emissions standards. This will allow us to gather information and work with interested parties in a separate process regarding these issues. EPA will work with all parties involved, including states, environmental organizations and manufacturers, to develop robust, creative, environmentally protective and cost-effective proposals addressing these issues.

a. Plans for a Future Manufacturer-Run In-Use Test Program

It is critical that nonroad diesel engines meet the applicable emission standards throughout their useful lives, to sustain those emission benefits over the broadest range of in-use operating conditions. The Agency believes that a manufacturer-run in-use testing program that is designed to generate data on in-use emissions of nonroad diesel engines can be used by EPA and the engine manufacturers to ensure that emissions standards are met throughout the useful life of the engines, under conditions normally experienced in-use. An effective program can be designed to monitor for NTE compliance and to help ensure overall compliance with emission standards.

The Agency expects to pattern the manufacturer-run in-use testing requirements for nonroad diesel engines after a program that is being developed for heavy-duty highway vehicles. In this latter program, EPA is committed to incorporating a two-year pilot program. The pilot program will allow the Agency and manufacturers to gain the necessary experience with the in-use testing protocols and generation of in-use test data using portable emission measurement devices prior to fully implementing program. A similar pilot program is expected to be part of any manufacturer-run in-use NTE test program for nonroad engines.

The Agency plans to promulgate the in-use testing requirements for heavy-duty highway vehicles in the December 2004 time frame. EPA anticipates proposing a manufacturer-run in-use testing program for nonroad diesel engines by 2005 or earlier. As mentioned above, the nonroad diesel engine program is expected to be patterned after the heavy-duty highway program.

b. Onboard Diagnostics

Today's notice does not propose to require onboard diagnostic (OBD) systems for non-road diesel vehicles and engines. However, EPA has committed to creating OBD requirements for heavy-duty highway engines/vehicles over 14,000 lbs GVWR and will develop OBD requirements for nonoad in conjunction with or following the highway OBD development. The Agency will propose nonroad diesel OBD requirements, along with heavy-duty highway OBD requirements, because OBD is necessary for maintaining and ensuring compliance with emission standards over the lifetime of engines. We will gather further information and coordinate with the heavy-duty highway and nonroad diesel industry and other stakeholders to develop proposed OBD system requirements.

E. Are the Proposed New Standards Feasible?

Prior to 1990, diesel engines could be broadly grouped into two categories; indirect-injection (IDI) diesel engines that were relatively inexpensive while providing somewhat better fuel economy compared to gasoline engines, and direct-injection (DI) diesel engines that were substantially more expensive but which offered better fuel economy. The majority of diesel engines fell into the first category, especially in the case of passenger cars, smaller heavy-duty trucks and most nonroad engines below 200 horsepower.

Diesel engine technology has changed rapidly since the early 1990s with the widespread use of electronics, onboard computers and the rise to preeminence of turbocharged direct-injection diesel engines. While some IDI engines remain, especially in the low horsepower portion of the nonroad market, most new diesel engines (including higher horsepower nonroad diesel engines) are turbocharged and direct-injected. Today's diesel engine has significantly improved, compared to historic engines with regard to issues of most concern to the user including noise, vibration, visible smoke emissions, startability, and performance. At the same time environmental benefits have also been realized with lower NO_X emissions, lower PM emissions, and improving fuel economy. These changes have been most pronounced for smaller diesel engines applied in passenger cars and light-heavy trucks. Acceptance of the technology by the public, especially in Europe, has lead to a rapid increase in diesel use for smaller vehicles with diesel sales for passenger cars exceeding 50 percent in some countries.

At the end of the 1990s continuing concern regarding the serious risk to public health and welfare from diesel emissions and the emergence of new emission control technologies enabled by low sulfur fuels led policy makers to set new future diesel fuel specifications and to set challenging new diesel emission standards for highway vehicles. In the United States, the EPA has set stringent new diesel emission standards for heavy-duty highway engines which will go into effect in 2007. These new standards are predicated on the use of Catalyzed Diesel Particulate Filters (CDPFs) which when used with less than 15ppm sulfur diesel fuel can reduce PM emissions by well over 90%, and on the use of NO_X adsorber catalyst technology which when used with less than 15 ppm diesel fuel can reduce NO_X emissions by more than 90%. When these technologies are fully implemented, the resulting diesel engine emissions will be 98% lower than the levels common to these diesel engines before 1990.

EPA has been conducting an ongoing technology progress review to measure industry progress to develop and introduce the needed clean fuel and clean engine technologies by 2007. The first in what will be a series of reports was published by EPA in June of 2002.[128] In the report, we concluded that technology developments by industry were progressing rapidly and that the necessary catalyzed diesel particulate filter and NO_X adsorber technologies would be available for use by 2007.

Nonroad diesel engines are fundamentally similar to highway diesel engines. As noted above in section III.B, in many cases, virtually identical engines are certified and sold for use in highway vehicles and nonroad equipment. Thus, emission control technologies developed for diesel engines can in general be applied to both highway and nonroad engines giving appropriate considerations to unique aspects of each application.

Today, we are proposing to set stringent new standards for a broad category of nonroad diesel engines. At the same time we are proposing to dramatically lower the sulfur level in nonroad diesel fuel ultimately to 15 ppm. We believe these standards are feasible given the availability of the clean 15 ppm sulfur fuel and the rapid progress to develop the needed emission control technologies. We acknowledge that these standards will be challenging for industry to meet in part due to differences in operating conditions and duty cycles for nonroad diesel engines. Also, we recognize that transferring and effectively applying these technologies, which have largely been developed for highway engines, will require additional lead time. We have given consideration to these issues in determining the appropriate timing and emission levels for the standards proposed today.

The following sections will discuss how these technologies work, issues specific to the application of these technologies to new nonroad engines, and why we believe that the emission standards proposed here are feasible. A more in-depth discussion of these technologies can be found in the draft RIA associated with this proposal, in the final RIA for the HD2007 emission standards and in the recently completed 2002 Highway Diesel Progress Review.[129] The following discussion summarizes the more detailed discussion found in the Draft RIA.

1. Technologies To Control NO_X and PM Emissions From Mobile Source Diesel Engines

Present mobile source rules control the emissions of non-methane hydrocarbons (NMHC), oxides of nitrogen (NO_X), carbon monoxide (CO), air toxics and particulate matter (PM) from diesel engines. Of these, PM and NO_X emissions are typically the most difficult to control. CO and NMHC emissions are inherently low from diesel engines and under most conditions can be controlled to low levels without difficulty. NMHC emissions also serve as a proxy for some of the air toxic emissions from these engines, since many air toxics are a component of NMHC and are typically reduced in proportion to NMHC reductions. Most diesel engine emission control technologies are designed to reduce PM and NO_X emissions without increasing CO and NMHC emissions above the already low diesel levels. Technologies to control PM and NO_X emissions are described below separately. We also discuss the potential for these technologies to decrease CO and NMHC emissions as well as their potential to reduce emissions of air toxics.

a. PM Control Technologies

Particulate matter from diesel engines is made of three components;

- Solid carbon soot,
- Volatile and semi-volatile organic matter, and
- Sulfate.

The formation of the solid carbon soot portion of PM is inherent in diesel engines due to the heterogenous distribution of fuel and air in a diesel combustion system. Diesel combustion is designed to allow for overall lean (excess oxygen) combustion giving good efficiencies and low CO and HC emissions with a small region of rich (excess fuel) combustion within the fuel injection plume. It is within this excess fuel region of the combustion that PM is formed when high temperatures and a lack of oxygen cause the fuel to pyrolize, forming soot. Much of the soot formed in the engine is burned during the combustion process as the soot is mixed with oxygen in the cylinder at high temperatures. Any soot that is not fully burned before the exhaust valve is opened will be emitted form the engine as diesel PM.

The soot portion of PM emissions can be reduced by increasing the availability of oxygen within the cylinder for soot oxidation during combustion. Oxygen can be made more available by either increasing the oxygen content in-cylinder or by increasing the mixing of the fuel and oxygen in-cylinder. A number of technologies exist that can influence oxygen content and in-cylinder mixing including, improved fuel injection systems, air management systems, and combustion system designs.[130] Many of these PM reducing technologies offer better control of combustion in general, and better utilization of fuel allowing for

[128] Highway Diesel Progress Review, United States Environmental Protection Agency, June 2002, EPA 420-R–02–016. Copy available in EPA Air Docket A–2001–28.

[129] Highway Diesel Progress Review, United States Environmental Protection Agency, June 2002, EPA 420–R–02–016. Copy available in EPA Air Docket A–2001–28.

[130] The most effective means to reduce the soot portion of diesel PM engine-out is to operate the diesel engine with a homogenous method of operation rather than the typical heterogenous operation. In homogenous combustion, also called premixed combustion, the fuel is dispersed evenly with the air throughout the combustion system. This means there are no fuel rich/oxygen deprived regions of the system where fuel can be pyrolized rather than burned. Gasoline engines are typically premixed combustion engines. Homogenous combustion is possible with a diesel engine under certain circumstances, and is used in limited portions of engine operation by some engine manufacturers. Unfortunately, homogenous diesel combustion is not possible for most operation in today's diesel engine. We believe that more manufacturers will utilize this means to control diesel emissions within the limitations of the technology. A more in-depth discussion of homogenous diesel combustion can be found in the draft RIA.

improvements in fuel efficiency concurrent with reductions in PM emissions. Improvements in combustion technologies and refinements of these systems is an ongoing effort for highway engines and for some nonroad engines where emission standards or high fuel use encourage their introduction. The application of better combustion system technologies across the broad range of nonroad engines in order to meet the new emission standards proposed here offers an opportunity for significant reductions in engine-out PM emissions and possibly for reductions in fuel consumption. The soot portion of PM can be reduced further with aftertreatment technologies as discussed later in this section.

The volatile and semi-volatile organic material in diesel PM is often simply referred to as the soluble organic fraction (SOF) in reference to a test method used to measure its level. SOF is primarily composed of engine oil which passes through the engine with no or only partial oxidation and which condenses in the atmosphere to form PM. The SOF portion of diesel PM can be reduced through reductions in engine oil consumption and through oxidation of the SOF catalytically in the exhaust.

The sulfate portion of diesel PM is formed from sulfur present in diesel fuel and engine lubricating oil that oxidizes to form sulfuric acid (H_2SO_4) and then condenses in the atmosphere to form sulfate PM. Approximately two percent of the sulfur that enters a diesel engine from the fuel is emitted directly from the engine as sulfate PM.[131] The balance of the sulfur content is emitted from the engine as SO_2. Oxidation catalyst technologies applied to control the SOF and soot portions of diesel PM can inadvertently oxidize SO_2 in the exhaust to form sulfate PM. The oxidation of SO_2 by oxidation catalysts to form sulfate PM is often called sulfate make. Without low sulfur diesel fuel, oxidation catalyst technology to control diesel PM is limited by the formation of sulfate PM in the exhaust as discussed in more detail in Section III.F below.

There are two common forms of exhaust aftertreatment designed to reduce diesel PM, the diesel oxidation catalyst (DOC) and the diesel particulate filter (DPF). DOCs reduce diesel PM by oxidizing a small fraction of the soot emissions and a significant portion of the SOF emissions. Total DOC effectiveness to reduce PM emissions is normally limited to approximately 30 percent because the SOF portion of diesel PM for modern diesel engines is typically less than 30 percent and because the DOC increases sulfate emissions reducing the overall effectiveness of the catalyst. Limiting fuel sulfur levels to 15 ppm, as we have proposed today, allows DOCs to be designed for maximum effectiveness (nearly 100% control of SOF with highly active catalyst technologies) since their control effectiveness is not reduced by sulfate make (*i.e.*, there sulfate make rate is high but because the sulfur level in the fuel is low the resulting PM emissions are well controlled). A reduction in diesel fuel sulfur to 500 ppm as we are proposing today, is also directionally helpful for the application of DOCs. While 500 ppm sulfur fuel will not make the full range of highly active catalyst technologies available to manufacturers, it will decrease the amount of sulfate make and may allow for slightly more active (*i.e.*, effective) catalysts to be used. We believe that this is an additional benefit of the proposed 500 ppm sulfur fuel program. DOCs are also very effective at reducing the air toxic emissions from diesel engines. Test data shows that emissions of toxics such as polycyclic aromatic hydrocarbons (PAHs) can be reduced by more than 80 percent with a DOC.[132] DOCs also significantly reduce (by more than 80 percent) the already low HC and CO emissions of diesel engines.[133] DOCs are ineffective at controlling the solid carbon soot portion of PM. Therefore, even with 15 ppm sulfur fuel DOCs would not be able to achieve the level of PM control needed to meet the standard proposed today.

DPFs control diesel PM by capturing the soot portion of PM in a filter media, typically a ceramic wall flow substrate, and then by oxidizing (burning) it in the oxygen-rich atmosphere of diesel exhaust. The SOF portion of diesel PM can be controlled through the addition of catalytic materials to the DPF to form a catalyzed diesel particulate filter (CDPF).[134] The catalytic material is also very effective to promote soot burning. This burning off of collected PM is referred to as ''regeneration.'' In aggregate over an extended period of operation, the PM must be regenerated at a rate equal to or greater that its accumulation rate, or the DPF will clog. For a non-catalyzed DPF the soot can regenerate only at very high temperatures, in excess of 600°C, a temperature range which is infrequently realized in normal diesel engine operation (for many engines exhaust temperatures may never reach 600°C). With the addition of a catalytic coating to make a CDPF, the temperature necessary to ensure regeneration is decreased significantly to approximately 250°C, a temperature within the normal operating range for most diesel engines.[135]

However, the catalytic materials that most effectively promote soot and SOF oxidation are significantly impacted by sulfur in diesel fuel. Sulfur both degrades catalyst oxidation efficiency (*i.e.* poisons the catalyst) and forms sulfate PM. Both catalyst poisoning by sulfur and increases in PM emissions due to sulfate make influence our decision to limit the sulfur level of diesel fuel to 15 ppm as discussed in greater detail in section III.F.

Filter regeneration is affected by catalytic materials used to promote oxidation, sulfur in diesel fuel, engine-out soot rates, and exhaust temperatures. At higher exhaust temperatures soot oxidation occurs at a higher rate. Catalytic materials accelerate soot oxidation at a single exhaust temperature compared to non-catalyst DPFs, but even with catalytic materials increasing the exhaust temperature further accelerates soot oxidation.

Having applied 15 ppm sulfur diesel fuel and the best catalyst technology to promote low temperature oxidation (regeneration), the regeneration balance of soot oxidation equal to or greater than soot accumulation over aggregate operation simplifies to: are the exhaust temperatures high enough on aggregate to oxidize the engine-out PM rate? [136] The answer is yes, for most highway applications and many nonroad applications, as demonstrated by the widespread success of retrofit CDPF systems for nonroad equipment and the

[131] Exhaust and Crankcase Emission Factors for Nonroad Engine Modeling—Compression-Ignition, EPA420-P–02–016, NR–009B. Copy available in EPA Air Docket A–2001–28.

[132] ''Demonstration of Advanced Emission Control Technologies Enabling Diesel-Powered Heavy-Duty Engines to Achieve Low Emission Levels'', Manufacturers of Emission Controls Association, June 1999. Air Docket A–2001–28.

[133] ''Demonstration of Advanced Emission Control Technologies Enabling Diesel-Powered Heavy-Duty Engines to Achieve Low Emission Levels'', Manufacturers of Emission Controls Association, June 1999. Air Docket A–2001–28.

[134] With regard to gaseous emissions such as NMHCs and CO, the CDPF works in the same manner with similar effectiveness as the DOC (*i.e.*, NMHC and CO emissions are reduced by more than 80 percent).

[135] Engelhard DPX catalyzed diesel particulate filter retrofit verification, *www.epa.gov/otaq/retrofit/techlist-engelhard.htm,* a copy of this information is available in Air Docket A–2001–28.

[136] If the question was asked, ''without 15 ppm sulfur fuel and the best catalyst technology, are the exhaust temperatures high enough on aggregate to oxidize the engine-out PM rate?'' the answer would be no, for all but a very few nonroad or highway diesel engines.

use of both retrofit and original equipment CDPF systems for highway vehicles.[137] [138] [139] However, it is possible that for some nonroad applications the engine-out PM rate may exceed the soot oxidation rate, even with low sulfur diesel fuel and the best catalyst technologies. Should this occur, successful regeneration requires that either engine-out PM rates be decreased or exhaust temperatures be increased, both feasible strategies. In fact, we expect both to occur as highway based technologies are transferred to nonroad engines. As discussed earlier, engine technologies to lower PM emissions while improving fuel consumption are continuously being developed and refined. As these technologies are applied to nonroad engines driven by both new emission standards and market pressures for better products, engine-out PM rates will decrease. Similarly, techniques to raise exhaust temperatures periodically in order to initiate soot oxidation in a PM filter have been developed for highway diesel vehicles as typified by the PSA system used on more than 400,000 vehicles in Europe.[140] [141]

During our 2002 Highway Diesel Progress Review, we investigated the plans of highway engine manufacturers to use CDPF systems to comply with the HD2007 emission standards for PM. We learned that all diesel engine manufacturers intend to comply through the application of CDPF system technology. We also learned that the manufacturers are developing means to raise the exhaust temperature, if necessary, to ensure that CDPF regeneration occurs.[142] These technologies include modifications to fuel injection strategies, modifications to EGR strategies, and modifications to turbocharger control strategies. These systems are based upon the technologies used by the engine manufacturers to comply with the 2004 highway emission standards. In general, the systems anticipated to be used by highway manufacturers to meet the 2004 emission standards are the same technologies that engine manufacturers have indicated to EPA that they will use to comply with the Tier 3 nonroad regulations (*e.g.*, electronic fuel systems).[143] In a manner similar to highway engine manufacturers, we expect nonroad engine manufacturers to adapt their Tier 3 emission control technologies to provide back-up regeneration systems for CDPF technologies in order to comply with the standards we are proposing today. We have estimated costs for such systems in our cost analysis.

Emission levels from CDPFs are determined by a number of factors. Filtering efficiencies for solid particle emissions like soot are determined by the characteristics of the PM filter, including wall thickness and pore size. Filtering efficiencies for diesel soot can be 99 percent with the appropriate filter design.[144] Given an appropriate PM filter design the contribution of the soot portion of PM to the total PM emissions are negligible (less than 0.001 g/bhp-hr). This level of soot emission control is not dependent on engine test cycle or operating conditions due to the mechanical filtration characteristics of the particulate filter.

Control of the SOF portion of diesel soot is accomplished on a CDPF through catalytic oxidation. The SOF portion of diesel PM consists of primarily gas phase hydrocarbons in engine exhaust due to the high temperatures and only forms particulate in the environment when it condenses. Catalytic materials applied to CDPFs can oxidize a substantial fraction of the SOF in diesel PM just as the SOF portion would be oxidized by a DOC. However, we believe that for engines with very high SOF emissions the emission rate may be higher than can be handled by a conventionally sized catalyst resulting in higher than zero SOF emissions. If a manufacturer's base engine technology has high oil consumption rates, and therefore high engine-out SOF emissions (*i.e.*, higher than 0.04 g/bhp-hr), compliance with the 0.01 g/bhp-hr emission standard proposed today may require additional technology beyond the application of a CDPF system alone.[145]

Modern highway diesel engines have controlled SOF emission rates in order to comply with the existing 0.1 g/bhp-hr emission standards. For modern highway diesel engines, the SOF portion of PM is typically on a small fraction of the total PM emissions (less than 0.02 g/bhp-hr). This level of SOF control is accomplished by controlling oil consumption through the use of engine modifications (*e.g.*, piston ring design, the use of 4-valve heads, the use of valve stem seals, etc.).[146] Nonroad diesel engines may similarly need to control engine-out SOF emissions in order to comply with the standard proposed today. The means to control engine-out SOF emissions are well known and have additional benefits, as they decrease oil consumption reducing operating costs. With good engine-out SOF control (*i.e.*, engine-out SOF < 0.02 g/bhp-hr) and the application of catalytic material to the DPF, SOF emissions from CDPF equipped nonroad engines will contribute only a very small fraction of the total tailpipe PM emissions (less than 0.004 g/bhp-hr). Alternatively, it may be less expensive or more practical for some applications to ensure that the SOF control realized by the CDPF is in excess of 90 percent, thereby allowing for higher engine-out SOF emission levels.

The best means to reduce sulfate emissions from diesel engines is by reducing the sulfur content of diesel fuel and lubricating oils. This is one of the reasons that we have proposed today to limit nonroad diesel fuel sulfur levels to be 15ppm or less. The catalytic material on the CDPF is crucial to

[137] ''Particulate Traps for Construction Machines, Properties and Field Experience,'' 2000, SAE 2000–01–1923.

[138] Letter from Dr. Barry Cooper, Johnson Matthey, to Don Kopinski, U.S. EPA. Copy available in EPA Air Docket A–2001–28.

[139] EPA Recognizes Green Diesel Technology Vehicles at Washington Ceremony, Press Release from International Truck and Engine Company, July 27, 2001. Copy available in EPA Air Docket A–2001–28.

[140] There is one important distinction between the current PSA system and the kind of system that we project industry will use to comply with the Tier 4 standards. The PSA system incorporates a cerium fuel additive to help promote soot oxidation. The additive serves a similar function to a catalyst to promote soot oxidation at lower temperatures. Even with the use of the fuel additive passive regeneration is not realized on the PSA system and an active regeneration is conducted periodically involving late cycle fuel injection and oxidation of the fuel on an up-front diesel oxidation catalyst to raise exhaust temperatures. This form of supplemental heating to ensure infrequent but periodic PM filter regeneration has proven to be robust and reliable for more than 400,000 PSA vehicles. Our 2002 progress review found that other manufacturers will be introducing similar systems in the next few years without the use of a fuel additive.

[141] Nino, S. and Lagarrigue, M. ''French Perspective on Diesel Engines and Emissions,'' presentation at the 2002 Diesel Engine Emission Reduction workshop in San Diego, California, Air Docket A–2001–28.

[142] Highway Diesel Progress Review, United States Environmental Protection Agency, June 2002, EPA 420-R–02–016. Copy available in EPA Air Docket A–2001–28.

[143] ''Nonroad Diesel Emissions Standards Staff Technical Paper'', EPA420–R–01–052, October 2001. Copy available in EPA Air Docket A–2001–28.

[144] Miller, R. *et. al*, ''Design, Development and Performance of a Composite Diesel Particulate Filter,'' March 2002, SAE 2002–01–0323.

[145] SOF oxidation efficiency is typically better than 80 percent and can be better than 90 percent. Given a base engine SOF rate of 0.04 g/bhp-hr and an 80 percent SOF reduction a tailpipe emission of 0.008 can be estimated from SOF alone. This level may be too high to comply with a 0.01 g/bhp-hr standard once the other constituents of diesel PM (soot and sulfate) are added. In this case, SOF emissions will need to be reduced engine-out or SOF control greater than 90 percent will need to be realized by the CDPF.

[146] Hori, S. and Narusawa, K. ''Fuel Composition Effects on SOF and PAH Exhaust Emissions from DI Diesel Engines,'' SAE 980507.

ensuring robust regeneration and high SOF oxidation; however, it can also oxidize the sulfate in the exhaust with high efficiency. The result is that the predominant form of PM emissions from CDPF equipped diesel engines is sulfate PM. Even with 15ppm sulfur diesel fuel a CDPF equipped diesel engine can have total PM emissions including sulfate emissions as high as 0.009 g/bhp-hr over some representative operating cycles using conventional diesel engine oils.[147] Although this level of emissions will allow for compliance with our proposed PM emissions standard of 0.01 g/bhp-hr, we believe that there is room for reductions from this level in order to provide engine manufacturers with additional compliance margin. During our 2002 Highway Progress Review, we learned that a number of engine lubricating oil companies are working to reduce the sulfur content in engine lubricating oils. Any reduction in the sulfur level of engine lubricating oils will be beneficial. Similarly, as discussed above, we expect engine manufacturers to reduce engine oil consumption in order to reduce SOF emissions and secondarily to reduce sulfate PM emissions. While we believe that sulfate PM emissions will be the single largest source of the total PM from diesel engines, we believe with the combination of technology, and the appropriate control of engine-out PM, that sulfate and total PM emissions will be low enough to allow compliance with a 0.01 g/bhp-hr standard, except in the case of small engines with higher fuel consumption rates as described later in this section.

CDPFs have been shown to be very effective at reducing PM mass by reducing dramatically the soot and SOF portions of diesel PM. In addition, recent data show that they are also very effective at reducing the overall number of emitted particles when operated on low sulfur fuel. Hawker, *et. al.*, found that a CDPF reduced particle count by over 95 percent, including some of the smallest measurable particles (< 50 nm), at most of the tested conditions. The lowest observed efficiency in reducing particle number was 86 percent. No generation of particles by the CDPF was observed under any tested conditions.[148] Kittelson, *et al.*, confirmed that ultrafine particles can be reduced by a factor of ten by oxidizing volatile organics, and by an additional factor of ten by reducing sulfur in the fuel. Catalyzed PM traps efficiently oxidize nearly all of the volatile organic PM precursors (*i.e.* SOF), and the reduction of diesel fuel sulfur levels to 15ppm or less will substantially reduce the number of ultrafine PM emitted from diesel engines. The combination of CDPFs with low sulfur fuel is expected to result in very large reductions in both PM mass and the number of ultrafine particles.

As described here, the range of technologies available to reduce PM emissions is broad, extending from improvements to existing combustion system technologies to oxidation catalyst technologies to complete CDPF systems. The CDPF technology along with 15ppm or less sulfur diesel fuel is the system that we believe will allow engine manufacturers to comply with the 0.01 g/bhp-hr PM standard that we have proposed for a wide range of nonroad diesel engines. While it may be possible to apply CDPFs across the full range of nonroad diesel engine sizes, the complexity of full diesel particulate filter systems makes application to the smallest range of diesel engines difficult to accurately forecast at this time. As described in the following sections, the Agency has given consideration to the engineering complexity, cost and packaging of these systems in setting emission standards for various nonroad engine power categories.

b. NO_X Control Technologies

Oxides of nitrogen (NO and NO_2, collectively called NO_X) are formed at high temperatures during the combustion process from nitrogen and oxygen present in the intake air. The NO_X formation rate is exponentially related to peak cylinder temperatures and is also strongly related to nitrogen and oxygen content (partial pressures). NO_X control technologies for diesel engines have focused on reducing emissions by lowering the peak cylinder temperatures and by decreasing the oxygen content of the intake air. A number of technologies have been developed to accomplish these objectives including fuel injection timing retard, fuel injection rate control, charge air cooling, exhaust gas recirculation (EGR) and cooled EGR. The use of these technologies can result in significant reductions in NO_X emissions, but are limited due to practical and physical constraints of heterogeneous diesel combustion.[149 150]

EPA is investigating strategies to address these limitations of heterogenous diesel combustion in a research program. This concept consists of higher intake charge boost levels using a low-pressure loop cooled EGR system, combined with a proprietary fuel injection and combustion system to control engine-out NO_X.[151] The results from prototype laboratory research engines show NO_X control consistent with the standards proposed today. The technology must still overcome the limitations of increased PM emissions at low NO_X levels as well as other practical considerations of performance and durability. EPA intends to continue investigating this technology, but at this time cannot project that this technology would be generally available for use in compliance with the proposed standards.

A new form of diesel engine combustion, commonly referred to as homogenous diesel combustion or premixed diesel combustion, can give very low NO_X emissions over a limited range of diesel engine operation. In the regions of diesel engine operation over which this combustion technology is feasible (light load conditions), NO_X emissions can be reduced enough to comply with the 0.3 g/bhp-hr NO_X emission standard that we have proposed today.[152] Some engine manufacturers are today producing engines which utilize this technology over a narrow range of engine operation.[153] Unfortunately, it is not possible today to apply this technology over the full range of diesel engine operation. We do believe that more engine manufacturers will utilize this alternative combustion approach in the limited range over which it is effective, but will have to rely on conventional heterogenous diesel combustion for the bulk of engine operation. Therefore, we believe that catalytic NO_X emission control technologies will be required in order to realize the NO_X emission standards proposed today. Catalytic emission control technologies can extend the reduction of NO_X emissions

[147] *See* Table III.F.1 below.

[148] Hawker, P., *et al.*, Effect of a Continuously Regenerating Diesel Particulate Filter on Non-Regulated Emissions and Particle Size Distribution, SAE 980189.

[149] Flynn, P. *et al*, ''Minimum Engine Flame Temperature Impacts on Diesel and Spark-Ignition Engine NO_X Production,'' SAE 2000–01–1177, March 2000.

[150] Dickey, D. *et al*, ''NO_X Control in Heavy-Duty Diesel Engines—What is the Limit?,'' SAE 980174, February 1998.

[151] Gray, Charles ''Assessing New Diesel Technologies,'' November 2002, MIT Light Duty Diesel Workshop, available on MIT's website or in Air Docket A–2001–28. *http://web.mit.edu/chrisng/www/dieselworkshop_files/Charles%20Gray.PDF.*

[152] Stanglmaier, Rudolf and Roberts, Charles ''Homogenous Charge Compression Ignition (HCCI): Benefits, Compromises, and Future Engine Applications''. SAE 1999–01–3682.

[153] Kimura, Shuji, *et al.*, ''Ultra-Clean Combustion Technology Combining a Low-Temperature and Premixed Combustion Concept for Meeting Future Emission Standards'', SAE 2001–01–0200.

by an additional 90 percent or more over conventional ''engine-out'' control technologies alone.

NO_X emissions from gasoline-powered vehicles are controlled to extremely low levels through the use of the three-way catalyst technology first introduced in the 1970s. Three-way-catalyst technology is very efficient in the stoichiometric conditions found in the exhaust of properly controlled gasoline-powered vehicles. Today, an advancement upon this well-developed three-way catalyst technology, the NO_X adsorber, has shown that it too can make possible extremely low NO_X emissions from lean-burn engines such as diesel engines.[154] The potential of the NO_X adsorber catalyst is limited only by its need for careful integration with the engine and engine control system (as was done for three-way catalyst equipped passenger cars in the 1980s and 1990s) and by poisoning of the catalyst from sulfur in the fuel. The Agency set stringent new NO_X standards for highway diesel engines beginning in 2007 predicated upon the use of the NO_X adsorber catalyst enabled by significant reductions in fuel sulfur levels (15 ppm sulfur or less). In today's action, we are proposing similarly stringent NO_X emission standards for nonroad engines again using technology enabled by a reduction in fuel sulfur levels.

NO_X adsorbers work to control NO_X emissions by storing NO_X on the surface of the catalyst during the lean engine operation typical of diesel engines. The adsorber then undergoes subsequent brief rich regeneration events where the NO_X is released and reduced across precious metal catalysts. The NO_X storage period can be as short as 15 seconds and as along as 10 minutes depending upon engine-out NO_X emission rates and exhaust temperature. A number of methods have been developed to accomplish the necessary brief rich exhaust conditions necessary to regenerate the NO_X adsorber technology including late-cycle fuel injection, also called post injection, in exhaust fuel injection, and dual bed technologies with off-line regeneration.[155] [156] [157] This method for NO_X control has been shown to be highly effective when applied to diesel engines but has a number of technical challenges associated with it. Primary among these is sulfur poisoning of the catalyst as described in section III.F below. In the HD2007 RIA we identified four issues related to NO_X adsorber performance: performance of the catalyst across a broad range of exhaust temperatures, thermal durability of the catalyst when regenerated to remove sulfur (desulfated), management of sulfur poisoning, and system integration on a vehicle. In the HD 2007 RIA, we provided a description of the technology paths that we believed manufacturers would use to address these challenges. We are conducting an ongoing review of industry's progress to overcome these challenges and have updated our analysis of the progress to address these issues in the draft RIA associated with today's NPRM.

One of the areas that we have identified as needing improvement for the NO_X adsorber catalyst is performance at low and high exhaust temperatures. NO_X adsorber performance is limited at very high temperatures (due to thermal release of NO_X under lean conditions) and very low temperatures (due to poor catalytic activity for NO oxidation under lean conditions and low activity for NO_X reduction under rich conditions) as described extensively in the draft RIA. Our review of highway HD2007 technologies showed that significant progress has been made to broaden the temperature range of effective NO_X control of the NO_X adsorber catalysts (the temperature ''window'' of the catalyst). Every catalyst development company that we visited was able to show us new catalyst formulations with improved performance at both high and low temperatures. Similarly, many of the engine manufacturers we visited showed us data indicating that the improvements in catalyst formulations corresponded to improvements in emission reductions over the regulated test cycles. It is clear from the data presented to EPA that the progress with regard to NO_X adsorber performance has been both substantial and broadly realized by most technology developers. The importance of this temperature window to nonroad engine manufacturers is discussed in more detail later in this section.

Long term durability has been the greatest concern for the NO_X adsorber catalyst. We have concluded as described briefly in III.F below and in some detail in the draft RIA, that in order for NO_X adsorbers to effectively control NO_X emission throughout the life of a nonroad diesel engine the fuel sulfur level will have to be maintained at or below 15 ppm, that the NO_X adsorber catalyst thermal durability will need to improve in order to allow for sulfur regeneration events (since adsorber thermal degradation, ''sintering,'' is associated with each desulfation event, the number of desulfation events should be minimized), and that system improvements will have to be made in order to allow for appropriate management of sulfur poisoning. It is in this area of durability that NO_X adsorbers had the greatest need for improvement, and it is here where some of the most impressive ongoing strides in technology development have been made. During our ongoing review, we have learned that catalyst companies are making significant improvements in the thermal durability of the catalyst materials used in NO_X adsorbers. Similarly, the substrate manufacturers are developing new materials that address the problem of NO_X storage material migration into the substrate.[158] The net gain from these simultaneous improvements are NO_X adsorber catalysts which can be desulfated (go through a sulfur regeneration process) with significantly lower levels of thermal damage to the catalyst function. In addition, engine manufacturers and emission control technology vendors are developing new strategies to accomplish desulfation that allow for improved sulfur management while minimizing the damage due to sulfur poisoning. It was clear in our review that the total system improvements being made when coupled with changes to catalytic materials and catalyst substrates are delivering significantly improved catalyst durability to the NO_X adsorber technology.

Practical application of the NO_X adsorber catalyst in a vehicle was an issue during the HD2007 rulemaking and similarly there are issues regarding the application of NO_X adsorbers to nonroad equipment. Although there is considerable evidence that NO_X adsorbers are highly effective and that durability issues can be addressed, some worry that the application of the NO_X adsorber systems to vehicles and nonroad equipment will be impractical due to packaging constraints and the

[154] NO_X adsorber catalysts are also called, NO_X storage catalysts (NSCs), NO_X storage and reduction catalysts (NSRs), and NO_X traps.

[155] Johnson, T. ''Diesel Emission Control in Review—the Last 12 Months,'' SAE 2003–01–0039.

[156] Koichiro Nakatani, Shinya Hirota, Shinichi Takeshima, Kazuhiro Itoh, Toshiaki Tanaka, and Kazuhiko Dohmae, ''Simultaneous PM and NO_X Reduction System for Diesel Engines.'', SAE 2002–01–0957, SAE Congress March 2002.

[157] Schenk, C., McDonald, J. and Olson, B. ''High Efficiency NO_X and PM Exhaust Emission Control for Heavy-Duty On-Highway Diesel Engines,'' SAE 2001–01–1351.

[158] Some NO_X storage materials can interact with the catalyst substrate especially at elevated temperatures making the storage material unavailable for NO_X storage and weakening the substrate.

potential for high fuel consumption. Our review of progress has left us more certain than ever that practical system solutions can be applied to control emissions using NO_X adsorbers. We have tested a diesel passenger car (one of the most difficult packaging situations) with a complete NO_X adsorber and particulate filter system that demonstrated both exceptional emission control and very low fuel consumption.[159] Heavy-duty engine manufacturers have shared with us their improvements in system design and means to regenerate NO_X while minimizing fuel consumption.[160] Our own in-house testing program at the National Vehicle and Fuel Emissions Laboratory (NVFEL) is developing a number of novel ideas to reduce the total system package size while maintaining high levels of emission control and low fuel consumption rates as discussed more fully in the draft RIA. Similarly, a number of Department of Energy (DOE), Advanced Petroleum Based Fuel—Diesel Emission Control (APBF–DEC) program NO_X adsorber projects are working to address the system integration challenges for a diesel passenger car, a large sport utility vehicle and for a heavy heavy-duty truck.[161] By citing these numerous examples, we are not intending to imply that the challenge of integrating and packaging advanced emission control technologies is easy. Rather, we believe these examples show that even though significant challenges exist, they can be overcome through careful design and integration efforts. Nonroad equipment manufacturers have addressed similar challenges in the past when they have added additional customer features (*e.g.*, packaged an air-conditioning system) or in accommodating other emission control technologies (*e.g.*, charge air cooling systems).

All of the issues described above and highlighted first during the HD2007 rulemaking are likely to be concerns to nonroad engine and nonroad equipment manufacturers. We believe the challenge to overcome these issues will be significant for nonroad engines and equipment. Yet, we have documented substantial progress by industry in the last year to overcome these challenges, and we continue to believe based on the progress we have observed that the NO_X adsorber catalyst technology will be mature enough for application to many diesel engines by 2007. In the case of NO_X adsorber temperature window, which could be especially challenging for nonroad engines, we have performed an analysis summarized below in section III.E.2 and documented in the draft RIA, that leads us to conclude the technology can be successfully applied to nonroad engines provided there is some additional lead time for further engine and catalyst system technology development. Similarly, we acknowledge that the diverse nature and sheer number of different nonroad equipment types makes the challenge of packaging advanced emission control technologies more difficult. Therefore, we have included a number of equipment manufacturer flexibilities in the program proposed today in order to allow equipment manufacturers to manage the engineering resource challenges imposed by these regulations.

Another NO_X catalyst based emission control technology is selective catalytic reduction (SCR). SCR catalysts require a reductant, ammonia, to reduce NO_X emissions. Because of the significant safety concerns with handling and storing ammonia, most SCR systems make ammonia within the catalyst system from urea. Such systems are commonly called urea SCR systems. (Throughout this document the term SCR and urea SCR may be used interchangeably and should be considered as referring to the same urea based catalyst system.) With the appropriate control system to meter urea in proportion to engine-out NO_X emissions, urea SCR catalysts can reduce NO_X emissions by over 90 percent for a significant fraction of the diesel engine operating range.[162] Although EPA has not done an extensive analysis to evaluate its effectiveness, we believe it may be possible to reduce NO_X emissions with a urea SCR catalyst to levels consistent with compliance with the proposed NO_X standards.

However, we have significant concerns regarding a technology that requires extensive user intervention in order to function properly and the lack of the urea delivery infrastructure necessary to support this technology. Urea SCR systems consume urea in proportion to the engine-out NO_X rate. The urea consumption rate can be on the order of five percent of the engine fuel consumption rate. Therefore, unless the urea tank is prohibitively large, the urea must be replenished frequently. Most urea systems are designed to be replenished every time fuel is added or at most every few times that fuel is added. Today, there is not a system in place to deliver or dispense automotive grade urea to diesel fueling stations. One study conducted for the National Renewable Energy Laboratory (NREL), estimated that if urea were to be distributed to every diesel fuel station in the United States, the cost would be more than $30 per gallon.[163]

We are not aware of a proven mechanism that ensures that the user will replenish the urea supply as necessary to maintain emissions performance. Further, we believe given the additional cost for urea, that there will be significant disincentives for the end-user to appropriately replenish the urea because the cost of urea could be avoided without equipment performance loss. *See NRDC* v. *EPA,* 655 F. 2d 318, 332 (D.C. Cir. 1981) (referring to ‘‘behavioral barriers to periodic restoration of a filter by a [vehicle] owner’’ as a valid basis for EPA considering a technology unavailable). Due to the lack of an infrastructure to deliver the needed urea, and the lack of a track record of successful ways to ensure urea use, we have concluded that the urea SCR technology is not likely to be available for general use in the time frame of the proposed standards. Therefore, we have not based the feasibility or cost analysis of this emission control program on the use or availability of the urea SCR technology. However, we would not preclude its use for compliance with the emission standards provided that a manufacturer could demonstrate satisfactorily to the Agency that urea would be used under all conditions. We believe that only a few unique applications will be able to be controlled in a manner such that urea use can be assured, and therefore believe it is inappropriate to base a national emission control program on a technology which can serve effectively only in a few niche applications.

This section has described a number of technologies that can reduce

[159] McDonald, J and Bunker, B. ‘‘Testing of the Toyota Avensis DPNR at U.S. EPA–NVFEL,’’ SAE 2002–01–2877.

[160] Hakim, N. ‘‘NO_X Adsorbers for Heavy Duty Truck Engines—Testing and Simulation,’’ presentation at Motor Fuels: Effects on Energy Efficiency and Emissions in the Transportation Sector Joint Meeting of Research Program Sponsored by the USA Dept. of Energy, Clean Air for Europe and Japan Clean Air, October 9–10, 2002. Copy available in EPA Air Docket A–2001–28.

[161] Details with quarterly updates on the APBF-DEC programs can be found on the DOE website at the following location *http://www.ott.doe.gov/apbf.shtml.*

[162] ‘‘Demonstration of Advanced Emission Control Technologies Enabling Diesel-Powered Heavy-Duty Engines to Achieve Low Emission Levels’’, Manufacturers of Emissions Controls Association, June 1999 Air Docket A–2001–28.

[163] Fable, S. *et al,* ‘‘Subcontractor Report—Selective Catalytic Reduction Infrastructure Study,’’ AD Little under contract to National Renewable Energy Laboratory, July 2002, NREL/SR–5040–32689. Copy available in EPA Air Docket A–2001–28.

emissions from diesel engines. The following section describes the challenges to applying these diesel engine technologies to engines and equipment designed for nonroad applications.

2. Can These Technologies Be Applied to Nonroad Engines and Equipment?

The emission standards and the introduction dates for those standards, as described earlier in this section, are premised on the transfer of diesel engine technologies being or already developed to meet light-duty and heavy-duty vehicle standards that begin in 2007. The standards that we are proposing today for engines ≥75 horsepower will begin to go into effect four years later. This time lag between equivalent highway and nonroad diesel engine standards is necessary in order to allow time for engine and equipment manufacturers to further develop these highway technologies for nonroad engines and to align this program with nonroad Tier 3 emission standards that begin to go into effect in 2006.

As discussed previously, the test procedures and regulations for the HD2007 highway engines include a transient test procedure, a broad steady-state procedure, and NTE provisions that require compliant engines to emit at or below 1.5 times the regulated emission levels under virtually all conditions. An engine designed to comply with the 2007 highway emission standards would comply with the equivalent nonroad emission standards proposed today if it were to be tested over the transient and steady-state nonroad emission test procedures proposed today, which cover the same regions and types of engine operation. Said in another way, a highway diesel engine produced in 2007 could be certified in compliance with the transient and steady-state standards proposed today for nonroad diesel engines several years in advance of the date when these standards would go into effect. However, that engine, while compliant with certain of the nonroad emission standards proposed today, would not necessarily be designed to address the various durability and performance requirements of many nonroad equipment manufacturers. We expect that the engine manufacturers will need additional time to further develop the necessary emission control systems to address some of the nonroad issues described below as well as to develop the appropriate calibrations for engine rated speed and torque characteristics required by the diverse range of nonroad equipment. Furthermore, not all nonroad engine manufacturers produce highway diesel engines or produce nonroad engines that are developed from highway products. Therefore, there is a need for lead time between the Tier 3 emission standards which go into effect in 2006–2008 and the Tier 4 emission standards. We believe the technologies developed to comply with the Tier 3 emission standards such as improved air handling systems and electronic fuel systems will form an essential technology baseline which manufacturers will need to initiate and control the various regeneration functions required of the catalyst based technologies for Tier 4. The Agency has given consideration to all of these issues in setting the emission standards and the timing of those standards as proposed today.

This section describes some of the challenges to applying advanced emission control technologies to nonroad engines and equipment, and why we believe that technologies developed for highway diesel engines can be further refined to address these issues in a timely manner for nonroad engines consistent with the emission standards proposed today. This section paraphrases a more in-depth analysis in the draft RIA.

a. Nonroad Operating Conditions and Exhaust Temperatures

Nonroad equipment is highly diverse in design, application, and typical operating conditions. This variety of operating conditions affects emission control systems through the resulting variety in the torque and speed demands (*i.e.* power demands). This wide range in what constitutes typical nonroad operation makes the design and implementation of advanced emission control technologies more difficult. The primary concern for catalyst based emission control technologies is exhaust temperature. In general, exhaust temperature increases with engine power and can vary dramatically as engine power demands vary.

For most catalytic emission control technologies there is a minimum temperature below which the chemical reactions necessary for emission control do not occur. The temperature above which substantial catalytic activity is realized is often called the light-off temperature. For gasoline engines, the light-off temperature is typically only important in determining cold start emissions. Once gasoline vehicle exhaust temperatures exceed the light-off temperature, the catalyst is ''lit-off'' and remains fully functional under all operating conditions. Diesel exhaust is significantly cooler than gasoline exhaust due to the diesel engine's higher thermal efficiency and its operation under predominantly lean conditions. Absent control action taken by an electronic engine control system, diesel exhaust may fall below the light-off temperature of catalyst technology even when the vehicle is fully warmed up.

The relationship between the exhaust temperature of a nonroad diesel engine and light-off temperature is an important factor for both CDPF and NO_X adsorber technologies. For the CDPF technology, exhaust temperature determines the rate of filter regeneration and if too low causes a need for supplemental means to ensure proper filter regeneration. In the case of the CDPF, it is the aggregate soot regeneration rate that is important, not the regeneration rate at any particular moment in time. A CDPF controls PM emissions under all conditions and can function properly (*i.e.*, not plug) even when exhaust temperatures are low for an extended time and the regeneration rate is lower than the soot accumulation rate, provided that occasionally exhaust temperatures and thus the soot regeneration rate are increased enough to regenerate the CDPF. A CDPF can passively (without supplemental heat addition) regenerate if exhaust temperatures remain above 250°C for more than 30 percent of engine operation.[164] Similarly, there is a minimum temperature (*e.g.*, 200°C) for NO_X adsorbers below which NO_X regeneration is not readily possible and a maximum temperature (*e.g.*, 500°C) above which NO_X adsorbers are unable to effectively store NO_X. These minimum and maximum temperatures define a characteristic temperature window of the NO_X adsorber catalyst. When the exhaust temperature is within the temperature window (above the minimum and below the maximum) the catalyst is highly effective. When exhaust temperatures fall outside this window of operation, NO_X adsorber effectiveness is diminished. Therefore, there is a need to match diesel exhaust temperatures to conditions for effective catalyst operation under the various operating conditions of nonroad engines.

Although the range of products for highway vehicles is not as diverse as for nonroad equipment, the need to match exhaust temperatures to catalyst characteristics is still present. This is a significant concern for highway engine

[164] Engelhard DPX catalyzed diesel particulate filter retrofit verification, *www.epa.gov/otaq/retrofit/techlist-engelhard.htm*, a copy of this information is available in Air Docket A–2001–28.